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RADC TR-61-167

FEBRUARY 1961

DATA GATHERING INSTRUMENTATION

ENGINEERING STAFF
OF
SYSTEMS DEVELOPMENT DIVISION ORLANDO
RADIATION INCORPORATED
ORLANDO, FLORIDA

CONTRACT NO. AF30(602)-2209

Prepared For

ROME AIR DEVELOPMENT CENTER
AIR RESEARCH AND DEVELOPMENT COMMAND
UNITED STATES AIR FORCE
GRIFFISS AIR FORCE BASE
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ABSTRACT

The Airborne Time System, Radar Display System, and modification to Automatic Monitoring and Data Processing Systems (AMDPS) were designed, fabricated, installed, and checked out for Rome Air Development Center (RADC) on Contract AF30(602)-2209. Installation and checkout were accomplished at the Verona Test Site.

The Airborne Time System is an extension of the Time Signal Set AN/USQ-23(V). The system extended the range of the Time Signal Set from 2 miles to 200 miles. The time signal is prepared for transmission over a standard radio link. The signal is received in aircraft and the time code is then decoded for visual display and magnetic tape recording. Physical requirements of the Units were dependent upon aircraft environment.

The Radar Data Display System is used to distribute MSQ-1A and MOD-III radar range and azimuth information at several remote locations. The information is transmitted over an audio land line. The transmission method is serial on-off tone burst. The range and azimuth information is demodulated and stored for visual display at each remote site. A decimal readout is accomplished with nixie indicator tubes.

The Automatic Monitoring and Data Processing Equipment Data Recorder modification consisted of increasing the recording capability of the Data Recorder by better utilizing the total available recording time. In addition to increasing the recording capability, the recording cycle was altered to operate on a straight time basis and also on a per radar scan basis. This feature enabled the recording cycle to be in synchronism with the radar set associated with the Data Recorder.

Reliability and maintainability is presented, indicating the necessity of these factors being an important part of the design criterion of all phases of work. In the final section all phases of the work are summarized with a conclusion and recommendations of improvements and needed additional equipments reviewed.

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1.0 INTRODUCTION

The purpose of this report is to provide a technical review of the system design and a brief description of operation. A detailed description of the operation can be found in the Instruction Manuals. This report has been divided into sections and each section is then divided into three major subsections. Three subsections were chosen because there were three major phases to the contract, namely,

1) Airborne System,

2) Radar Display System, and

3) Modification to Automatic Monitoring and Data Processing Systems (AMDPS)

A general approach is presented which discusses the function of the three systems and a brief description of the major components. Physical descriptions, with illustrations, as well as general operating methods are available in this section.

General design philosophy and the factors affecting it are discussed in the section on the design approach. Mechanical and electrical design considerations are presented and are supplemented with photographs of the equipment.

Design and operating difficulties that were encountered and how these difficulties were eliminated are included. Some theory of operation is available here, however, only that circuitry which is necessary for explanation of design changes or difficulties is available since a detailed presentation is included in the Instruction Manuals.

The section on Reliability will summarize the reliability program accomplished during the work period, and there is a brief section on maintainability.

The information and results obtained from the above are summarized and conclusions are made regarding overall system operation, areas that need improving, and future capabilities of the equipment. Recommendations are contained which point out additions or alterations that should be considered for better operation and increased capabilities.

A brief description and function of the equipment provided by this contract is included in Table 1.

TABLE 1

EQUIPMENT DESCRIPTION

A. Airborne System

Unit	Quantity	Description
Transmitter-Modulator	1	Converts PWM Time Code to Frequency Shift Time Code and Modulates a Ground Transmitter.
Airborne Time Decoder	2	Accepts Frequency Shift Time Code, or Operates as Time Generator in absence of Frequency Shift Time Code, and provides parallel BCD and parallel Decimal Time Outputs.
Airborne Radidial	2	Presents Time in Six Decimal Digits (Nixies) suitable for Photography
B. Radar Display System		
Pick-Off Unit	1	Accepts Parallel BCD Range and Azimuth Information and transmits range and azimuth information in BCD Serial Tone Bursts on Land Lines.
Control Unit	6	Converts serial Tone Bursts into parallel BCD information for Display by Remote Visual Indicators (Nixies).
Decimal Readout Unit	14	Presents Range and Azimuth of one Radar Target in Six Decimal Digits (Nixies) suitable for photography

TABLE 1 (continued)

C. AMDPS Modification		
Modified AMDPS Data Recorder	6	Accepts: Parallel BCD Time information, parallel BCD information from five Blip/Scan Switchboxes, parallel BCD information from five Jamming Effectiveness Switchboxes, and fifteen Analog Voltages for BCD recording on a perforated paper tape formated for a Datatron 205 Computer. Capabilities are provided for the addition of the two groups of Parallel BCD Data for recording on the perforated tape. Recording can be commanded every 2 seconds or greater on a per scan rotation of a control PPI Scope.
Modified AMDPS Data Recorder	1	Accepts parallel BCD Time information from five Blip/Scan Switchboxes, parallel BCD information from five Jamming Effectiveness Switchboxes, and eleven Analog Voltages for BCD recording on a perforated paper tape formated for a Datatron 205 Computer. Recording can be commanded, on a per scan cycle of a control PPI Scope, every 1.4 seconds or greater.
Blip/Scan Switchboxes	10	Converts four station manual information to BCD information for recording by Modified AMDPS Data Recorders .
Jamming Effectiveness Switchboxes	10	Converts six station manual information for recording by Modified AMDPS Data Recorders

2.0 DISCUSSION

2.1 General

This section is intended to provide a general insight to the purpose and description of the various systems before the detailed system description, operation, and difficulties encountered during checkout and installation are presented.

A brief description of the various types of equipment installed throughout the Verona Site will be presented in this section. The Airborne System is discussed in Section 2.1.1, the Radar Display System is discussed in Section 2.1.2, and the modifications to the AMDPS Data Recorder are discussed in Section 2.1.3.

2.1.1 Airborne System

2.1.1.1 Transmitter Modulator

The transmitter modulator is a PWM/FM Converter. A serial pulse width modulated (PWM) time code from the Radiclock of the Time Signal Set AN/USQ-23(V) is the input to the Transmitter Modulator. The PWM code is converted to a frequency shift signal. The frequency shift signal at the output of the Transmitter Modulator is from a low output impedance amplifier. An output amplitude control is included to vary the amplitude to compensate for differences of transmitters. The power for the Transmitter Modulator is supplied by the Radiclock.

The front and rear views of the Transmitter Modulator are shown in Figures 1and 2. Figure 3 is an interior view.

The Transmitter Modulator is mounted on a standard panel that may be mounted in a standard relay rack.

2.1.1.2 Airborne Time Decoder

The frequency shift time code from the Transmitter Modulator is used to modulate a ground station transmitter. The output of the transmitter is detected by an airborne receiver. The output of the receiver, which is identical to the output of the Transmitter Modulator, is connected to the Airborne Time Decoder.

The serial frequency shift time code signal is converted to a parallel decimal and parallel BCD output in the Airborne Time Decoder. The frequency shift time signal is converted to a PWM time code by a discriminator. The PWM time code is stored in a shift register and when each code is collected, the code is transferred to a storage register. The output of the storage register is in parallel BCD form, one output of the storage register is available at the unit connector. The other output is matrixed from the storage register in Nixie drivers to result in a parallel decimal form.

The Airborne Time Decoder in addition to being used as slave to the transmitted time code can be used as a clock. Circuitry is included to recognize the absence of an input time signal or an erroneous input time signal. When these conditions are recognized, the Airborne Time Decoder is automatically switched from the slave mode of operation to the clock mode of operation. The clock mode of operation is controlled by a crystal oscillator to an accuracy of 0.01%. Time set switches are included to set initial time into the Airborne Time Decoder in absence of transmitted time.

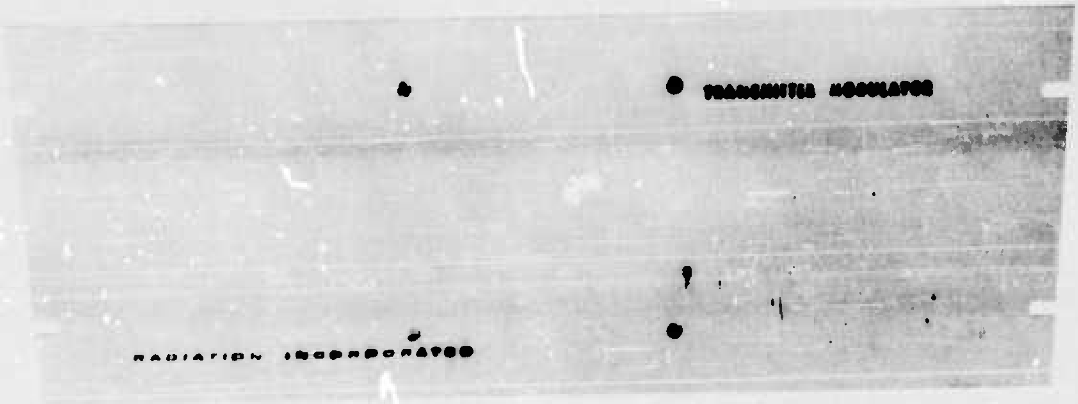

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Figure 1. Transmitter Modulator - Front View

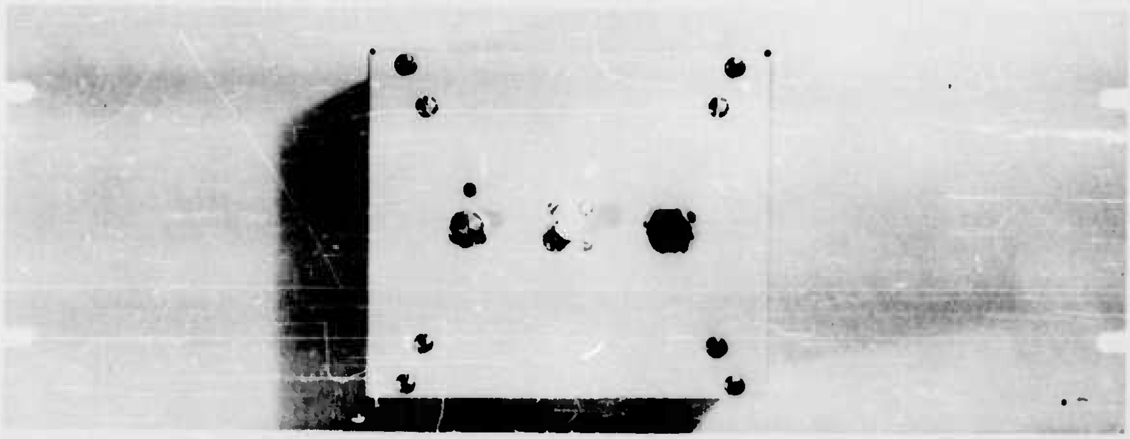

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Figure 2. Transmitter Modulator - Rear View

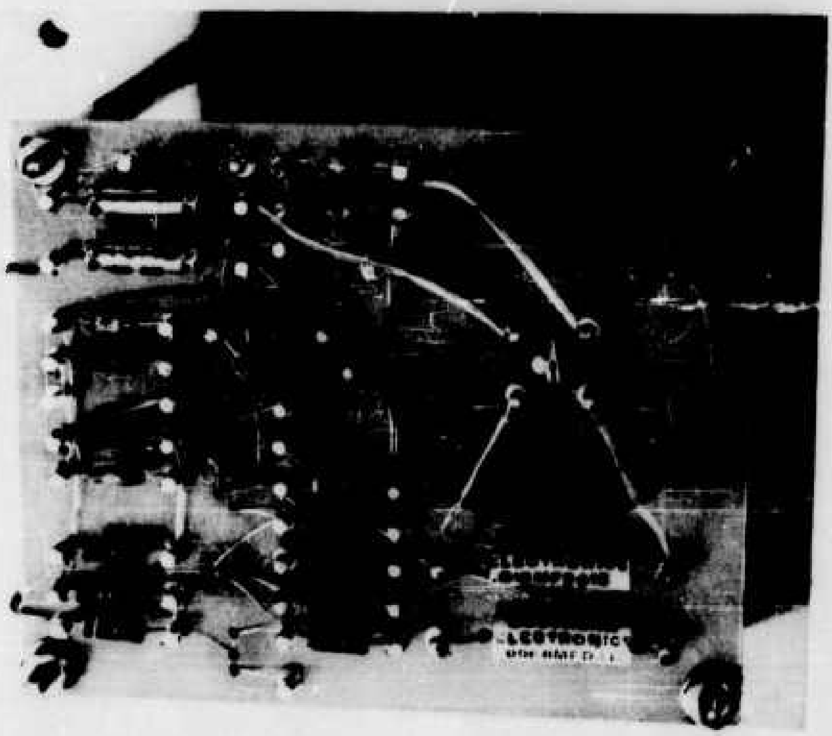

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Figure 3. Transmitter Modulator - Interior View

A front and rear view are shown in Figures 4 and 5. Figure 6 illustrates the unique construction features utilizing plug-in modules on metal swingout cards for ease of maintenance.

The Airborne Time Decoder is housed in a cabinet designed to be mounted on a standard size shock mount base. The cabinet has been constructed to minimize RF interference. This is accomplished by welding all joints and placing silver-plated finger stock around the cover.

Controls are placed in such a way as to convey the most likely sequence of usage to the operator. They are clearly labeled and in some cases illuminated for optimum visual operator cues.

2.1.1.3 Airborne Radidial

The Radidial is a visual indicator used to display the time of day in hours, minutes and seconds. The necessary voltages to operate the Nixie indicator tubes are obtained from the Nixie drivers located in the Airborne Time Decoder. The displayed time has a resolution of one second.

The Radidial mounting legs are attached by rubber sleeves for purposes of shock and vibration isolation. The Nixie tubes are also supported by rubber gaskets to isolate shock and vibration effects. The unit is approximately 2 inches high by 10 inches wide by 4 inches deep and weighs three pounds. A photograph of this unit is shown in Figure 7.

2.1.2 Radar Display System

2.1.2.1 Pick-Off Unit

The Pick-Off Unit is a converter and code transmitter. Parallel BCD range and azimuth information from the MSQ-1A and MOD-III radar is fed into the Pick-Off Unit. This information is in yards and counts of degrees where 72,000 counts represents 360°. This radar information is converted to nautical miles and degrees and is transmitted serially by land line in BCD tone bursts of 14.5KC and 12KC. The MSQ-1A radar information is at 14.5KC and the MOD-III information is at 12KC. The output code is shown in Figure 42. The code translation is accurate to within one mile of range and one degree of azimuth.

A front view of the Pick-Off Unit is shown in Figure 8. Figures 9 and 10 are a rear and interior view of the Pick-Off Unit. Swingout cards similar to the cards used in the Airborne Time Decoder are used. Plug-in modules mounted on the swingout cards afford ease in maintenance. Four swingout cards contain modules and one swingout card contains the modulator and oscillator.

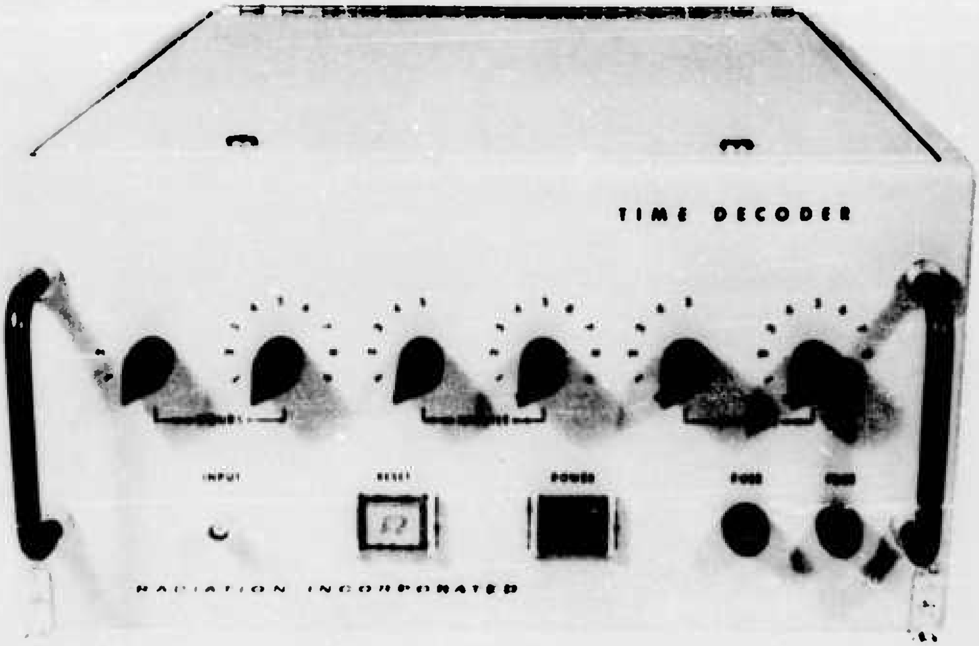

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Figure 4. Airborne Time Decoder – Front View

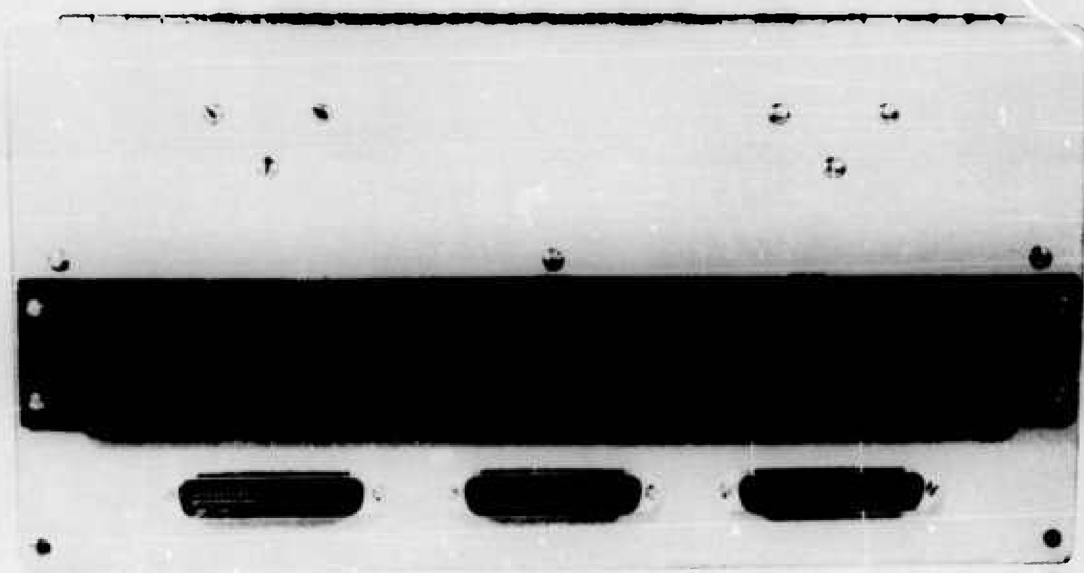

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Figure 5. Airborne Time Decoder – Rear View

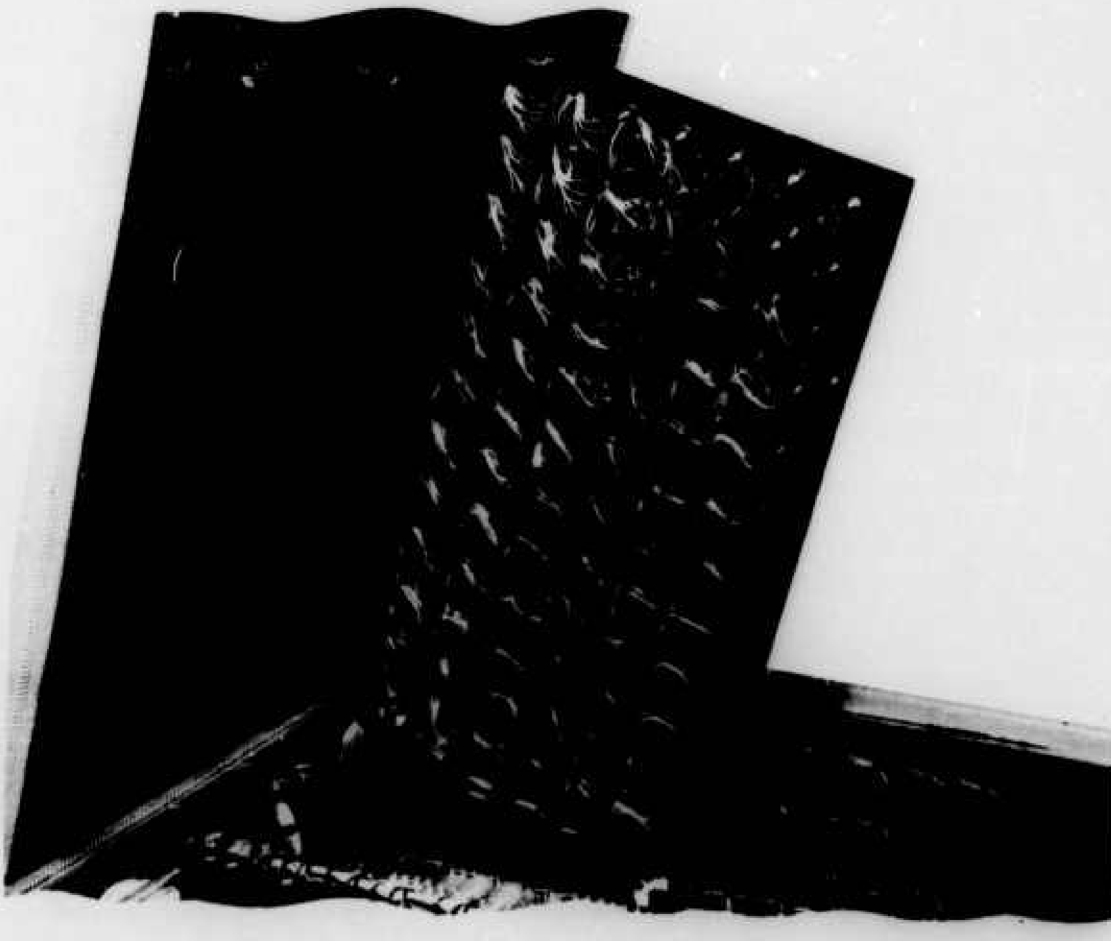

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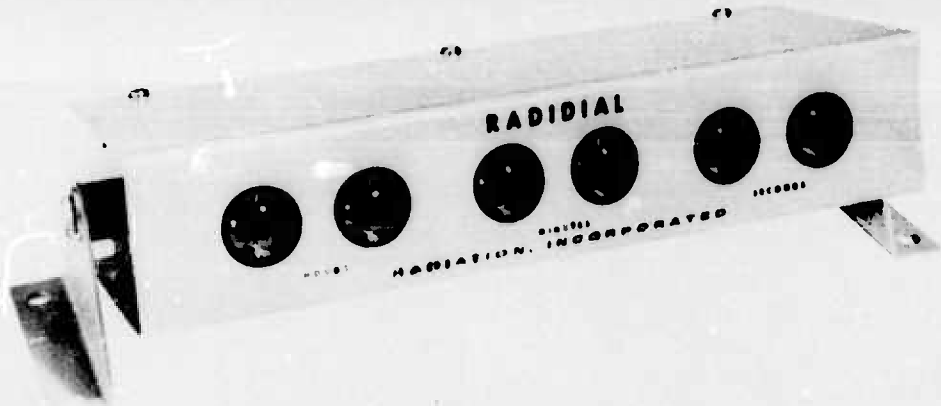
Figure 6. Airborne Decoder - One Card Extended



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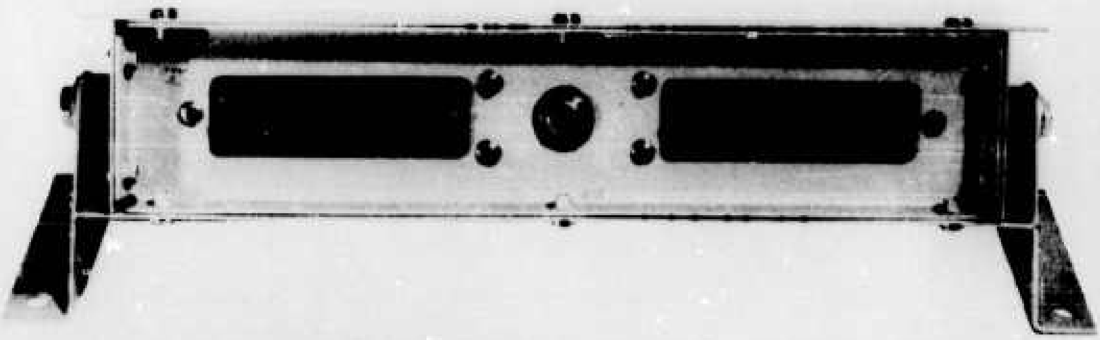
Front View



Rear View

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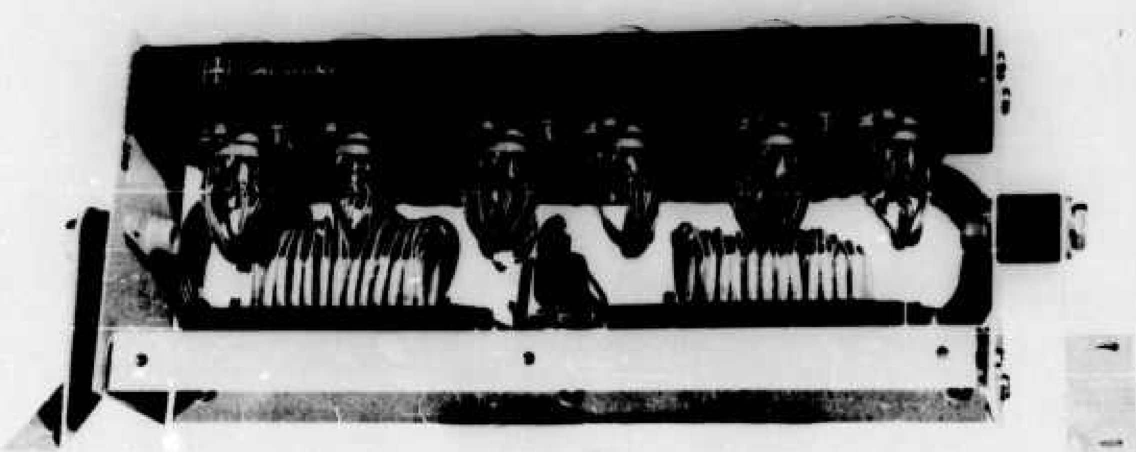

Interior View

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Figure 7. Airborne Radidial

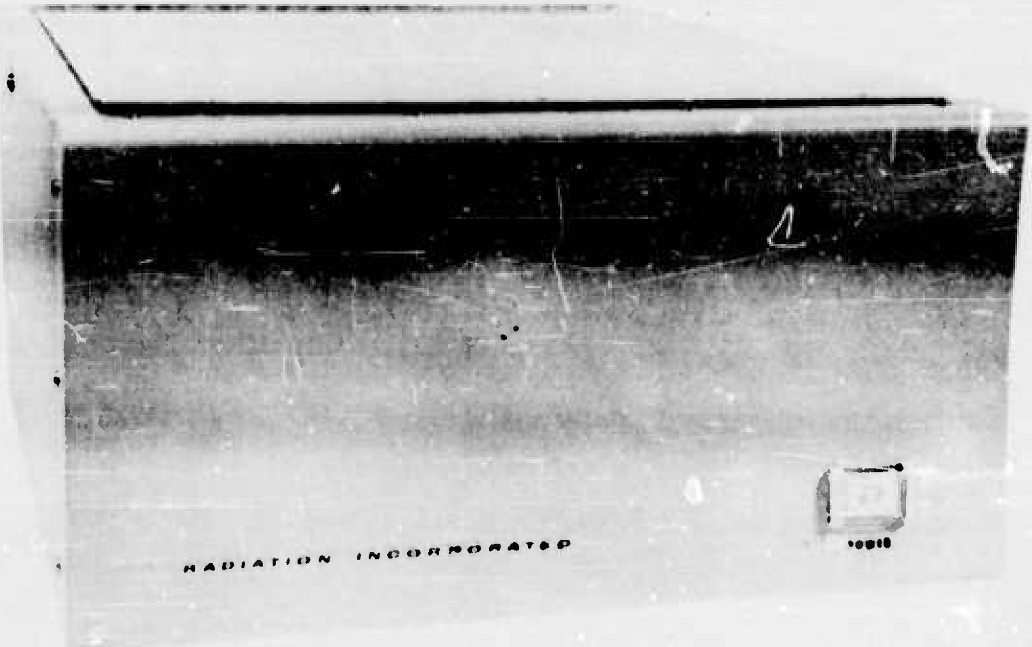

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Figure 8. Pickoff Unit - Front View

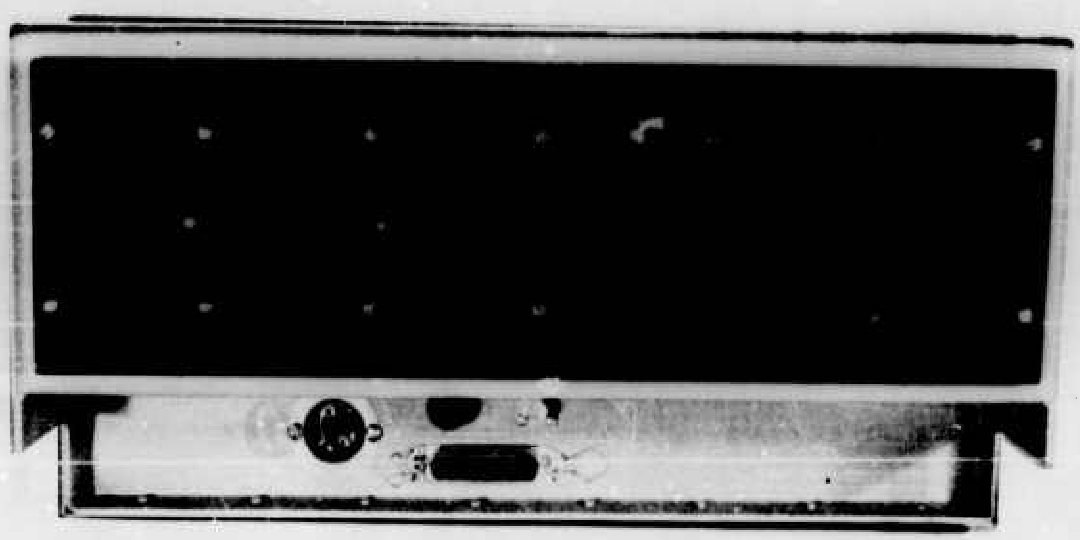

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Figure 9. Pickoff Unit - Rear View

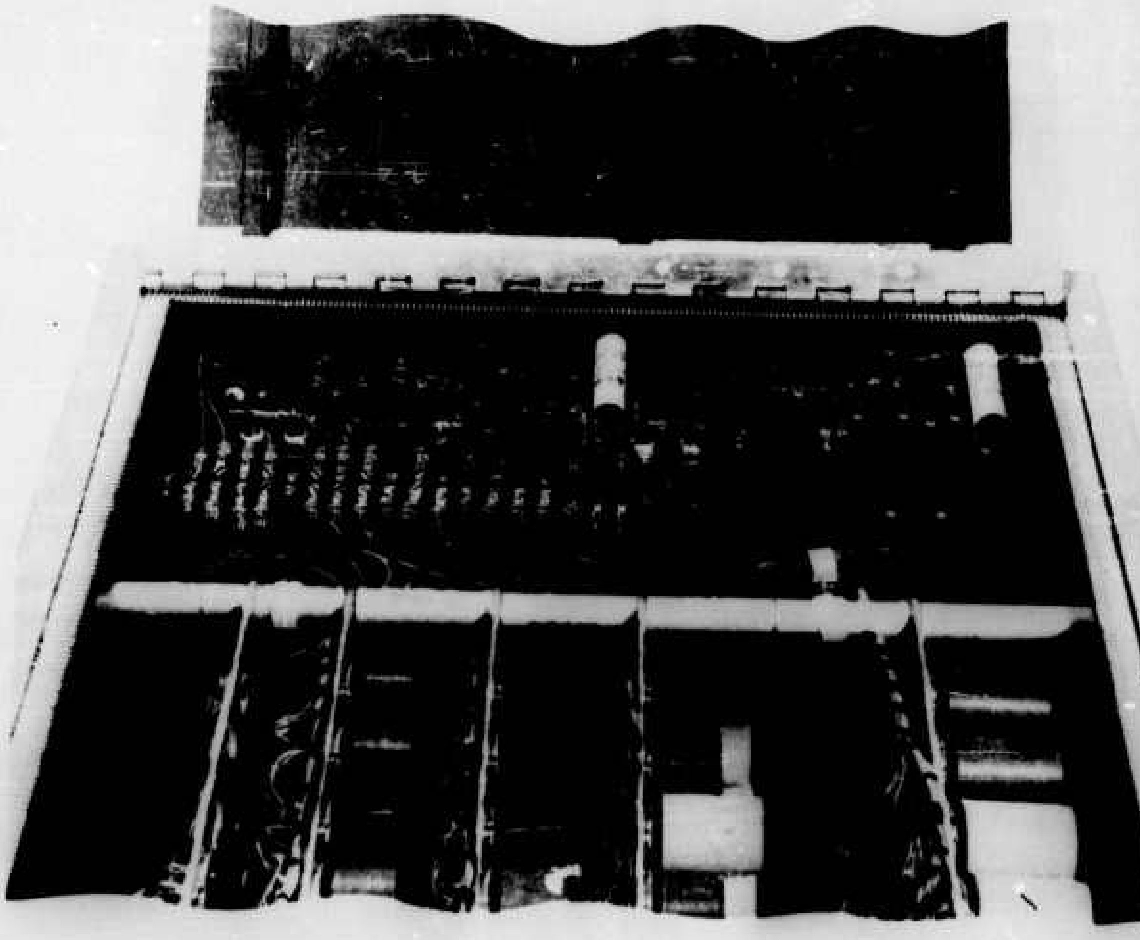

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Figure 10. Pickoff Unit - Interior View

The Pick-Off Unit is housed in a cabinet designed for either table top or rack mounting. However, rack mounting requires brackets and slides which are not provided. The cabinet is 8 1/2 x 10 x 32 inches and weighs approximately 54 pounds. The cabinet has been constructed to minimize RF interference. This is accomplished by placing silver-plated finger stock around the cover, welding all joints and by providing a double front panel.

2.1.2.2 Control Unit

The Control Unit serves as a demodulator and converter for the output of the Pick-Off Unit. The serial BCD data is received at a control unit where the information is demodulated and stored. The output of the Control Unit is parallel decimal code and parallel BCD code. The parallel decimal output is used to operate remote visual indicators. The Control Unit will control up to ten Decimal Readout Units.

Physically, the Conrrol Unit is identical in construction to the Pick-Off Unit with the exception of the front and rear panels, as illustrated in Figures 11 and 12. The Control Unit has six swingout cards with plug-in modules mounted on the cards.

2.1.2.3 Decimal Readout Unit

The Decimal Readout Unit is a visual indicator when connected to a control unit and is used to display range in miles and azimuth in degrees. The readout devices are Nixie tubes. The unit is seen in Figure 13.

2.1.3 AMDPS Modification

The purpose of the modifications to the AMDPS Recorder is to enable the Recorder to use recording time to a greater advantage. This was accomplished by recording data at the maximum punch rate. Prior to modification only 40 percent of the total recording capability on the output paper tape was being utilized. A second modification was an improved Blip/Scan switchbox and Jamming Effectiveness switchbox. The third modification was the addition of the "per radar scan" recording mode.

Mechanical modifications contributed a great part to the overall modifications and photographs are included which illustrate the condition of the recorder before and after the additions were provided, see Figure 14 through Figure 33.

Changes to the electronics and electrical circuitry of the recorder were designed so that existing circuitry was utilized to the greatest advantage, in order to minimize the amount of rewiring. Where existing circuitry could not be used, new circuit replacements have been substituted.

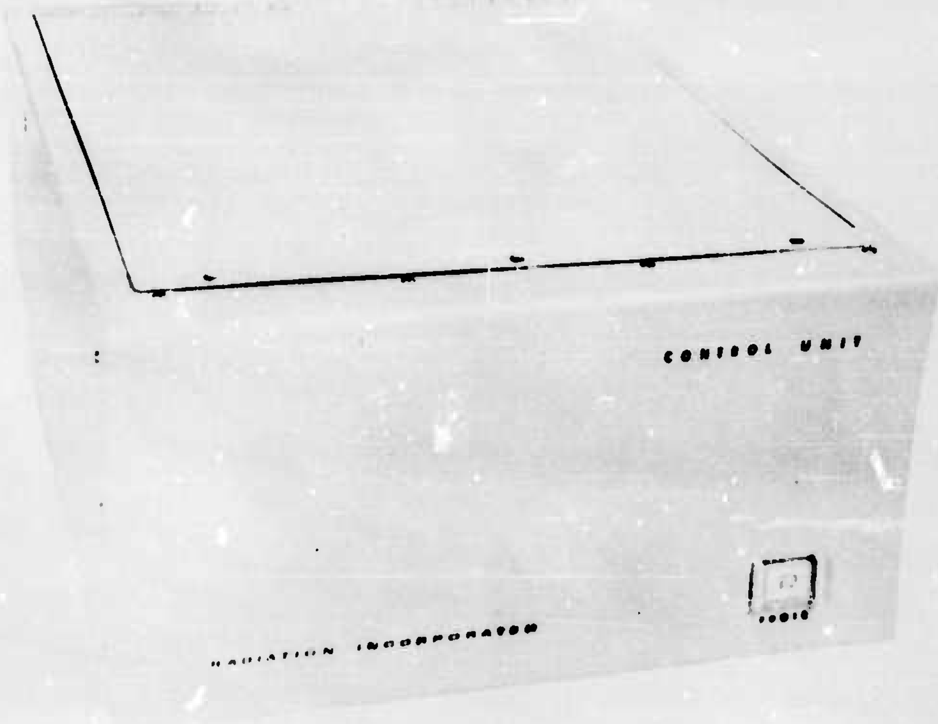

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Figure 11. Control Unit - Front View

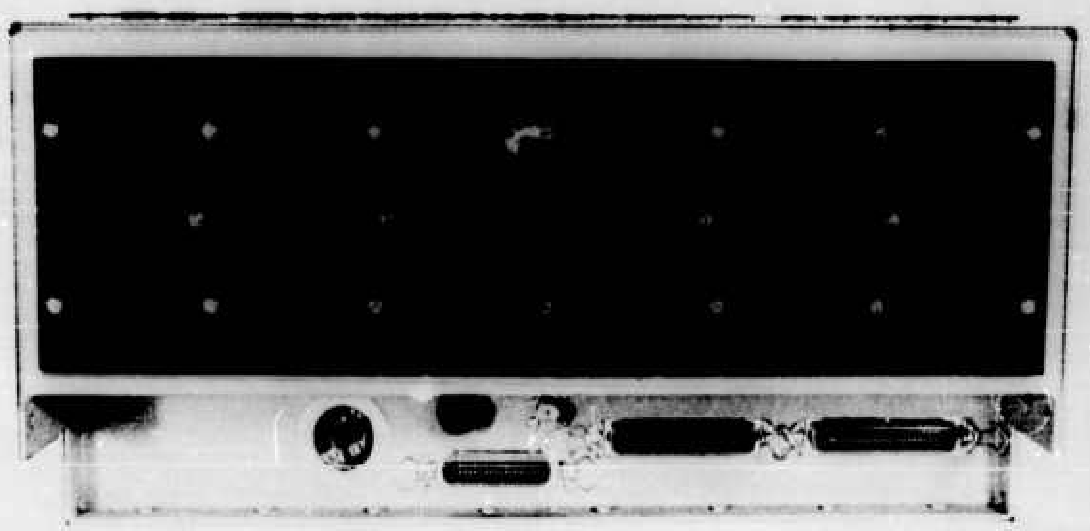

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Figure 12. Control Unit - Rear View

Front View

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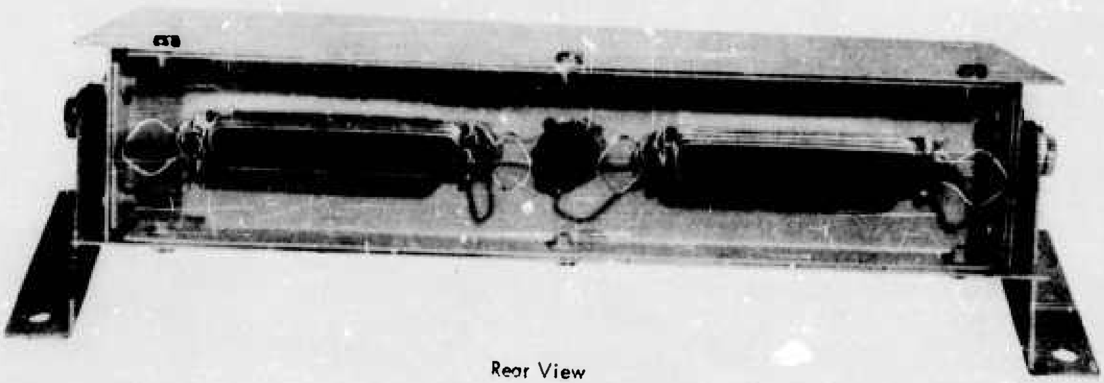

Rear View

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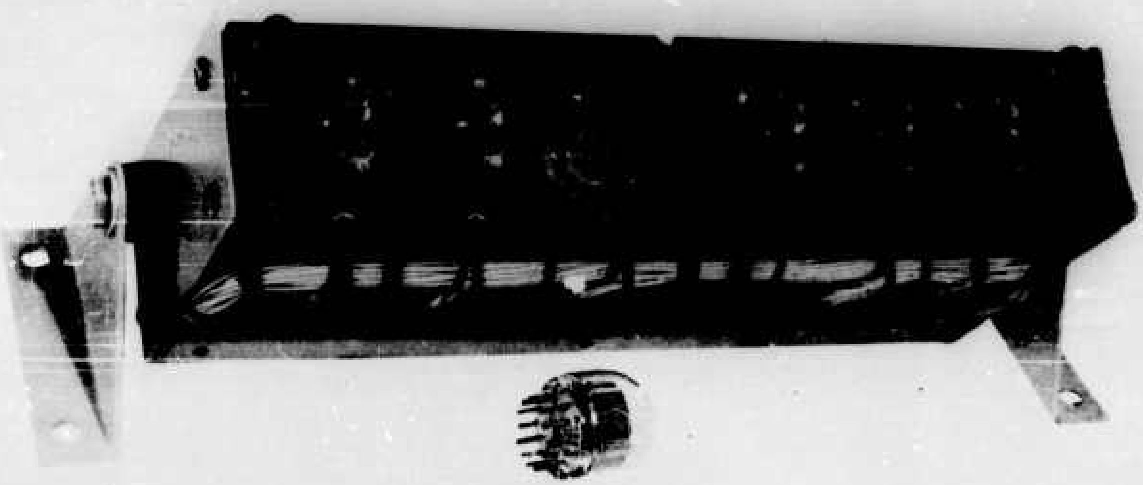

Interior View

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Figure 13. Decimal Readout Unit

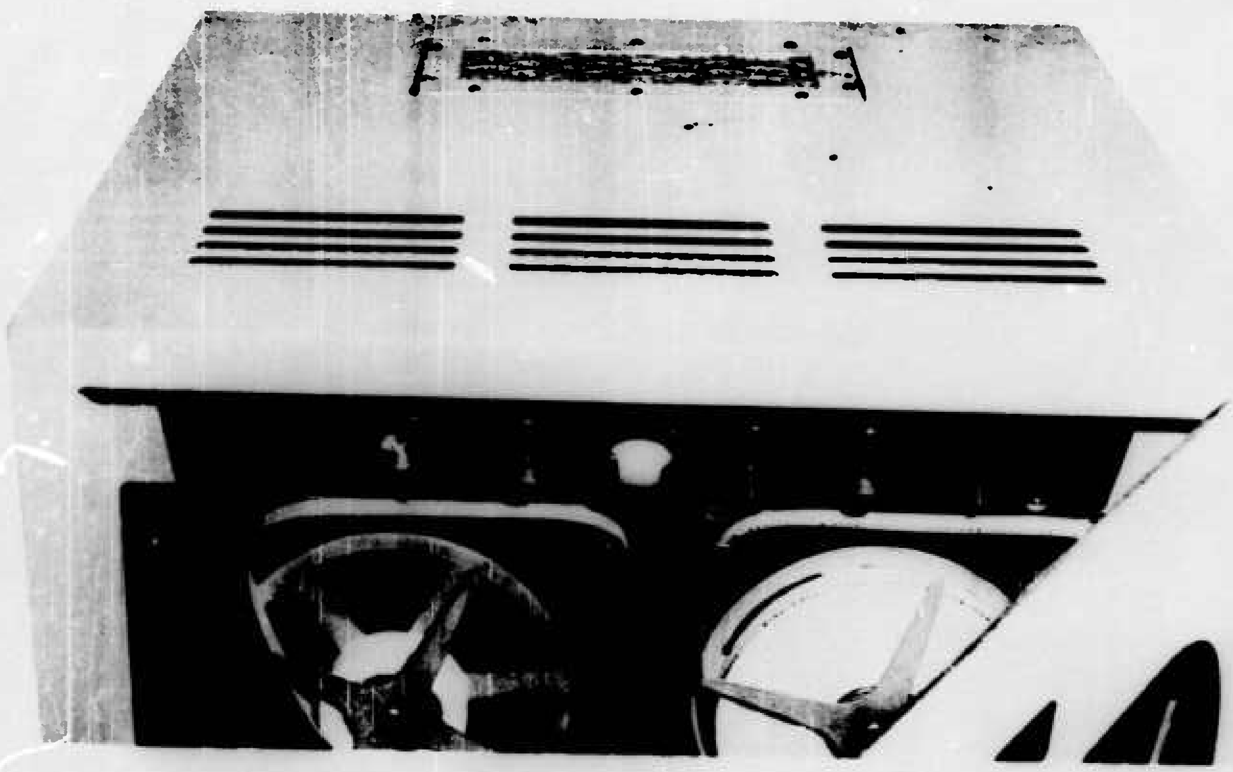

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Figure 14. AMDPS Data Recorder – Top View (PRE-MOD)

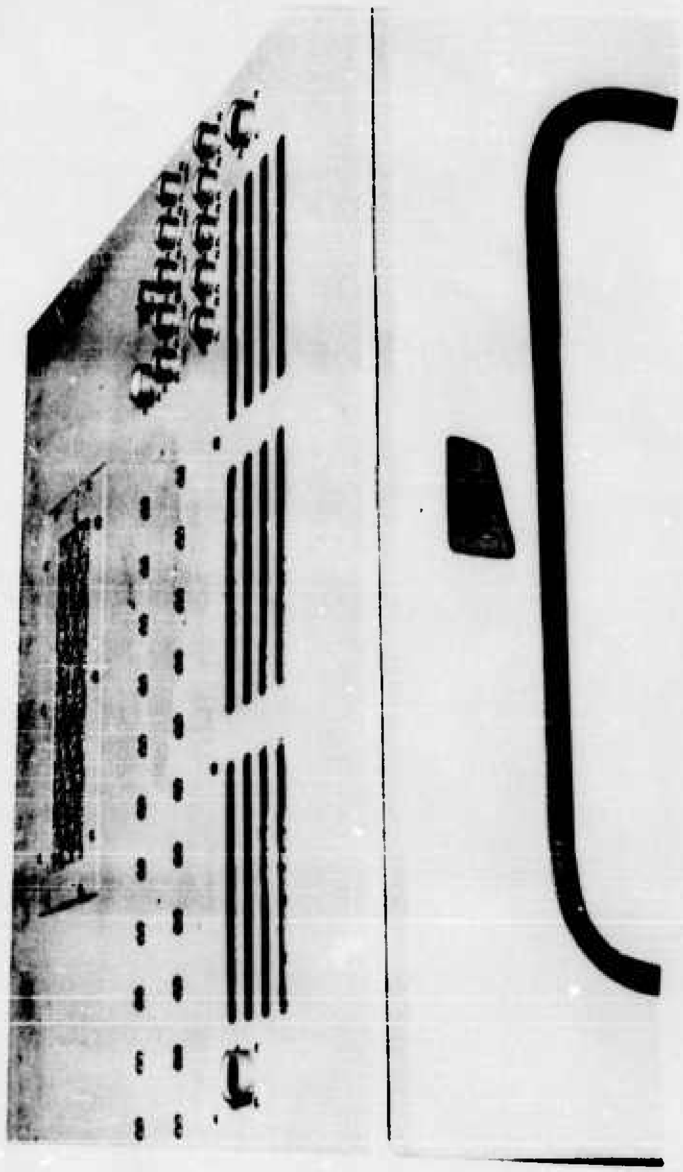

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Figure 15. AMDPS Data Recorder – Top View (MOD)

As a result of these modifications, the following capabilities have been added to the modified AMDPS Data Recorders located as shown in Figure 34.

2.1.3.1 Recording of Time

Verona Range time from a Raditrand, AN/USQ-23(V), is now recorded on the output tape. The old method was the stamping of time on the tape with a time clock. This meant all the recorders had an independent time base. With this modification, all recorders now record a synchronized time code.

2.1.3.2 Datatron 205 Word

Two parameters are now contained in each Datatron 205 word. This modification doubled the amount of data recorded in each word. The original method had only one parameter recorded in each datatron word.

2.1.3.3 Analog and Digital Inputs

Capability of recording both digitized analog inputs and digital inputs on the output tape was added. The AMDPS recorded only digitized analog inputs prior to this modification.

2.1.3.4 Punch Selection

All operational parameters and maintenance parameters are now recorded on one tape and either of two punches may be selected. The previous method utilized one punch for operational parameters and the second punch for the maintenance parameters.

2.1.3.5 Scan

The AMDPS will now operate in one of two selected modes. One is a scan basis, where one complete recording cycle on the output tape represents one complete rotation of the antenna associated with the radar being monitored by the AMDPS. A second operating mode is a straight time basis with the output tape operating every two seconds or an even multiple of two seconds. The previous method did not provide for operation on a per scan basis or a recording cycle other than one second.

2.1.3.6 Blip/Scan and Jamming Effectiveness Switchboxes

The old switchboxes have been replaced by new switchboxes that incorporate features not available in the former switchboxes. Only

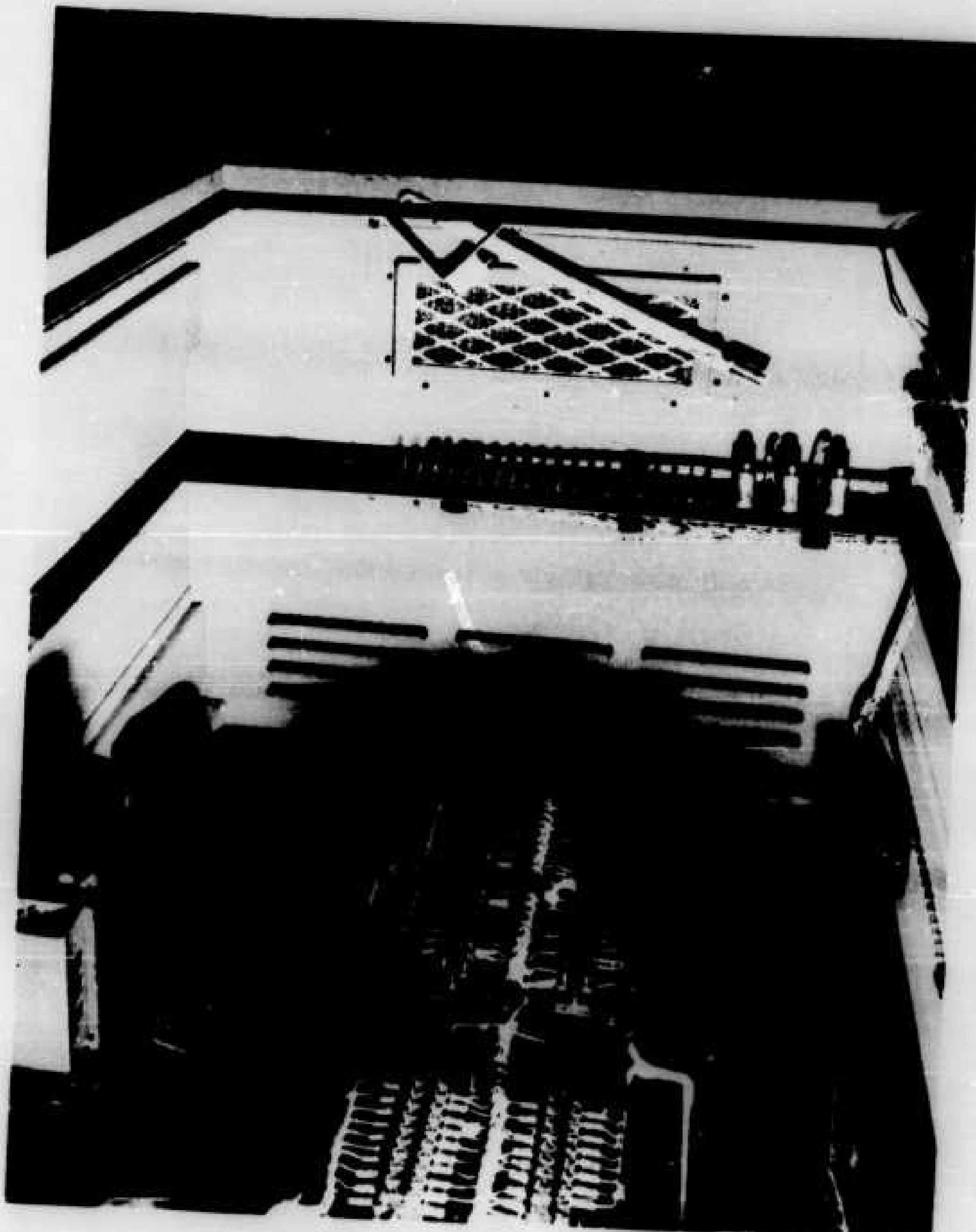

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Figure 16. AMDPS Data Recorder - Top View, Interior (PRE-MOD)

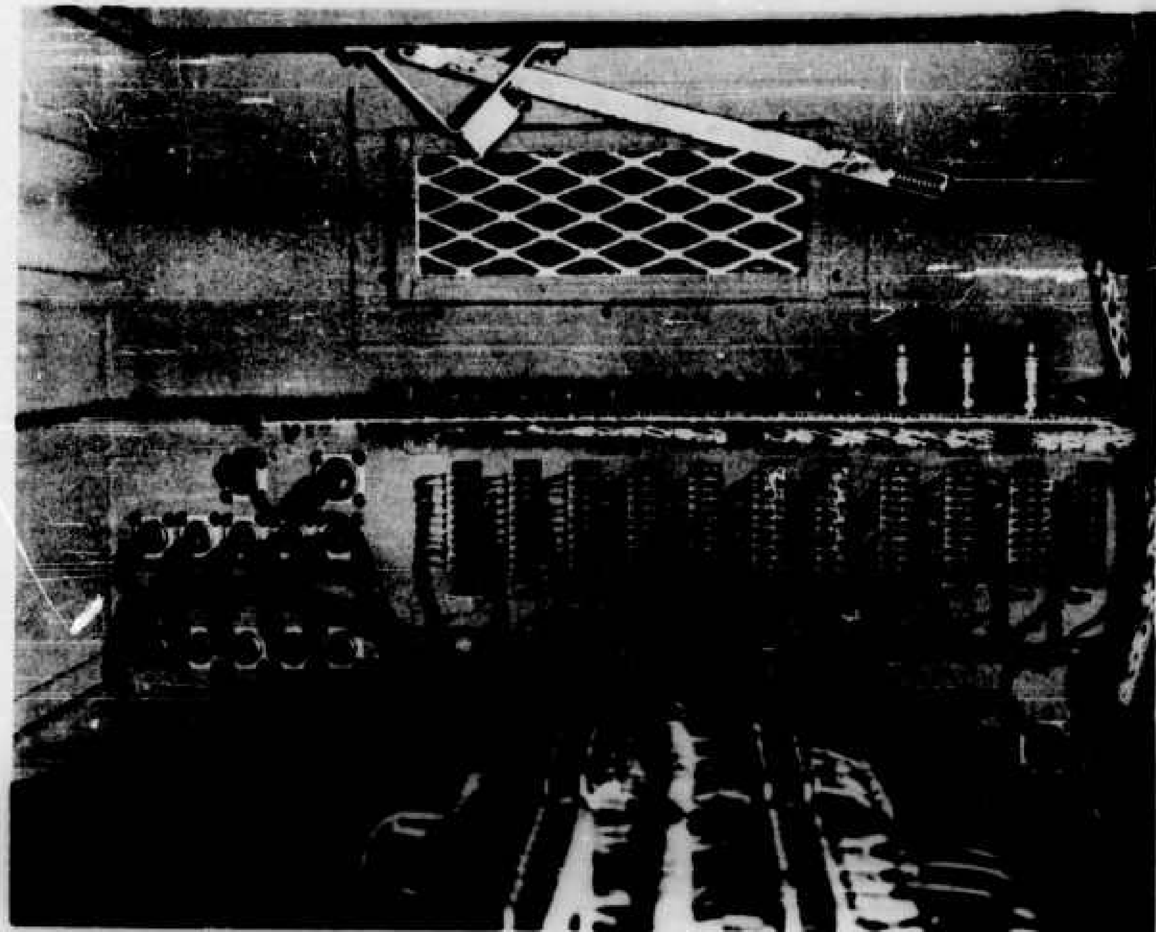

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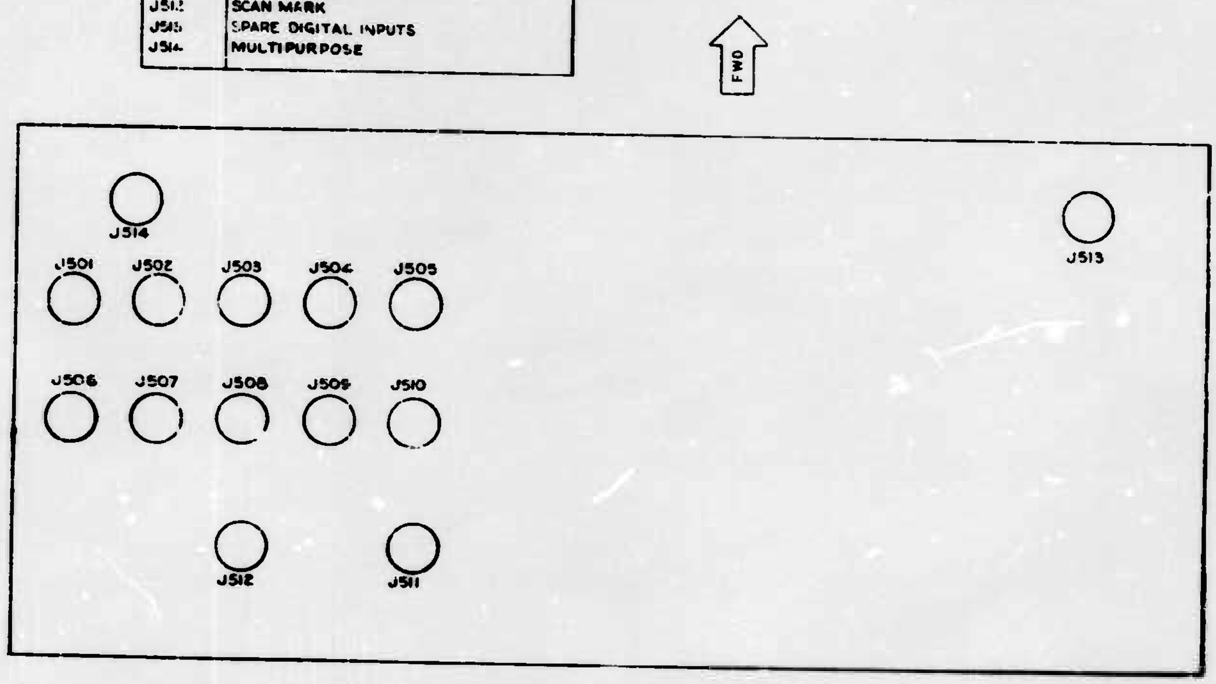
Figure 17. AMDPS Data Recorder - Top View, Interior (MOD)

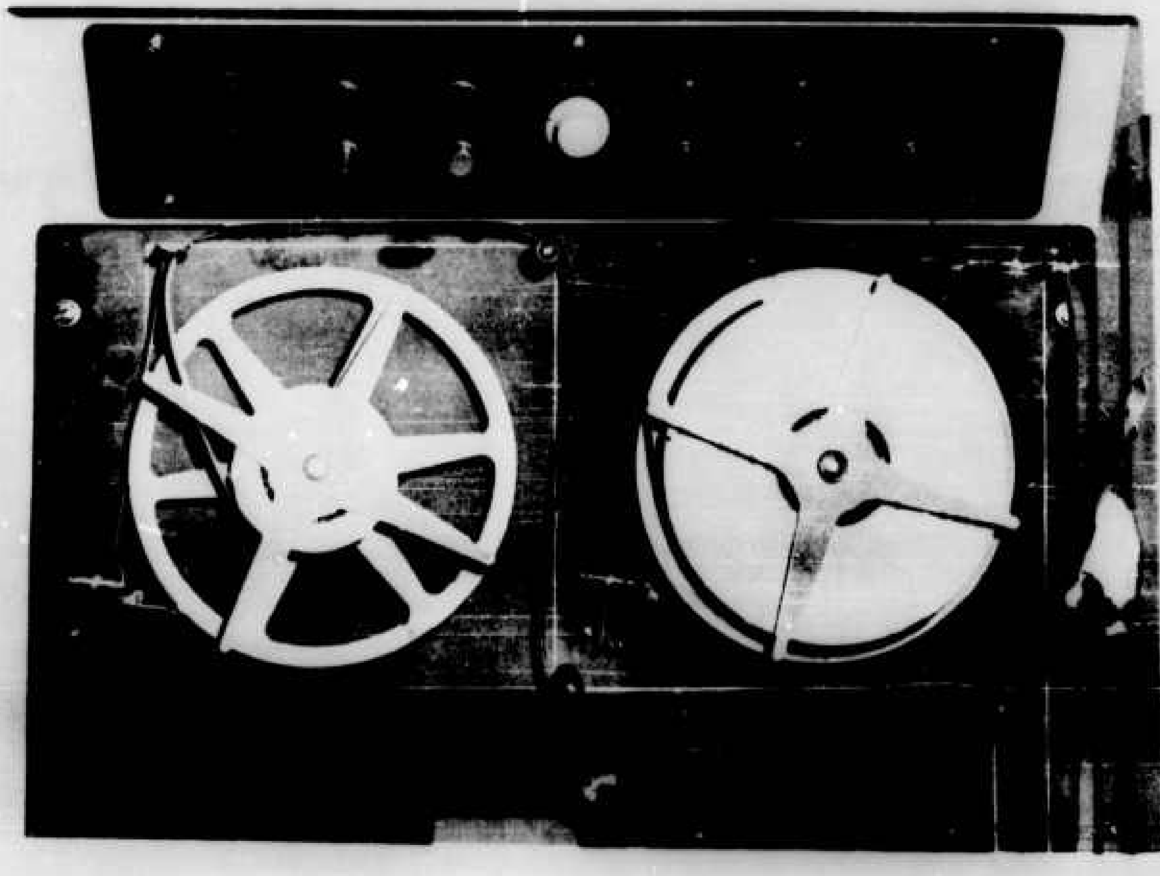
CONNECTOR NUMBER	FUNCTION
J501	BLIP/SCAN NO. 5
J502	BLIP/SCAN NO. 4
J503	BLIP/SCAN NO. 3
J504	BLIP/SCAN NO. 2
J505	BLIP/SCAN NO. 1
J506	JAMMING EFFECTIVENESS NO. 5
J507	JAMMING EFFECTIVENESS NO. 4
J508	JAMMING EFFECTIVENESS NO. 3
J509	JAMMING EFFECTIVENESS NO. 2
J510	JAMMING EFFECTIVENESS NO. 1
J511	TIME INPUTS
J512	SCAN MARK
J513	SPARE DIGITAL INPUTS
J514	MULTIPURPOSE



NOTE:
1. J501 THRU J510 - AMPHENOL CONNECTOR 67-02E-14-18S
2. J511 - AMPHENOL CONNECTOR 67-02E-18-24P
3. J512 - AMPHENOL CONNECTOR 67-02E-14-5S
4. J513 - AMPHENOL CONNECTOR 67-02E-20-27S
5. J514 - AMPHENOL CONNECTOR 67-02E-18-24S

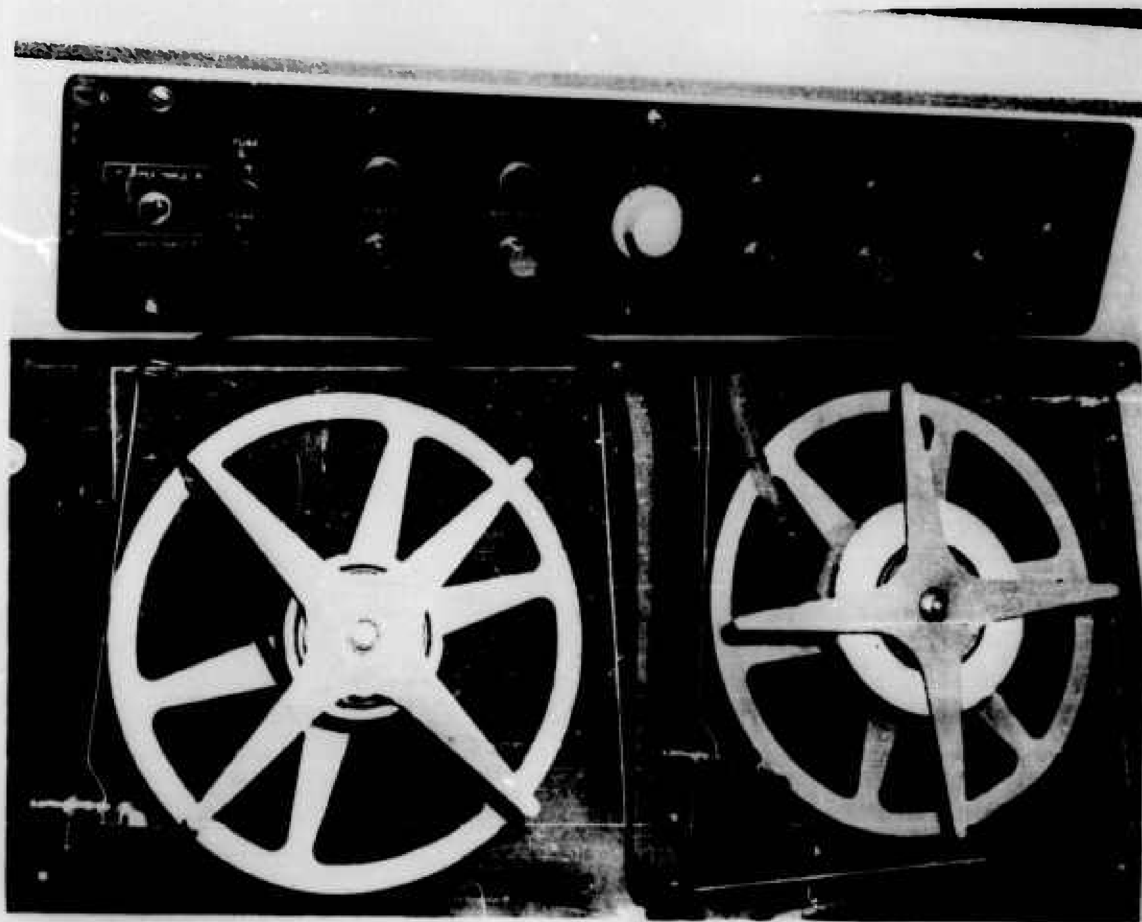
25794

Figure 13. AMDPS Data Recorder – Connector Layout (MOD)



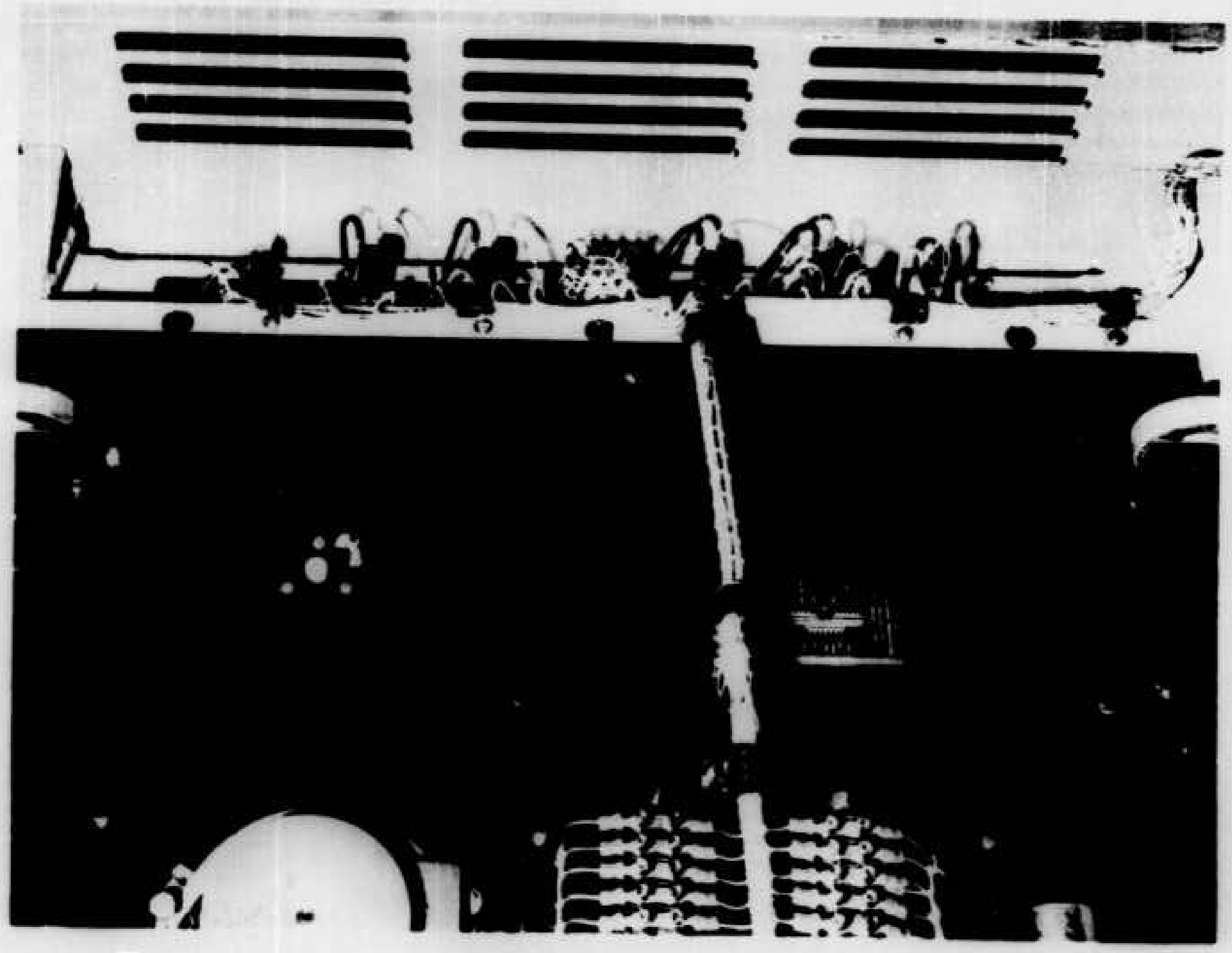
27309

Figure 19. AMDPS Data Recorder - Data Recorder Panel Front View (PRE-MOD)



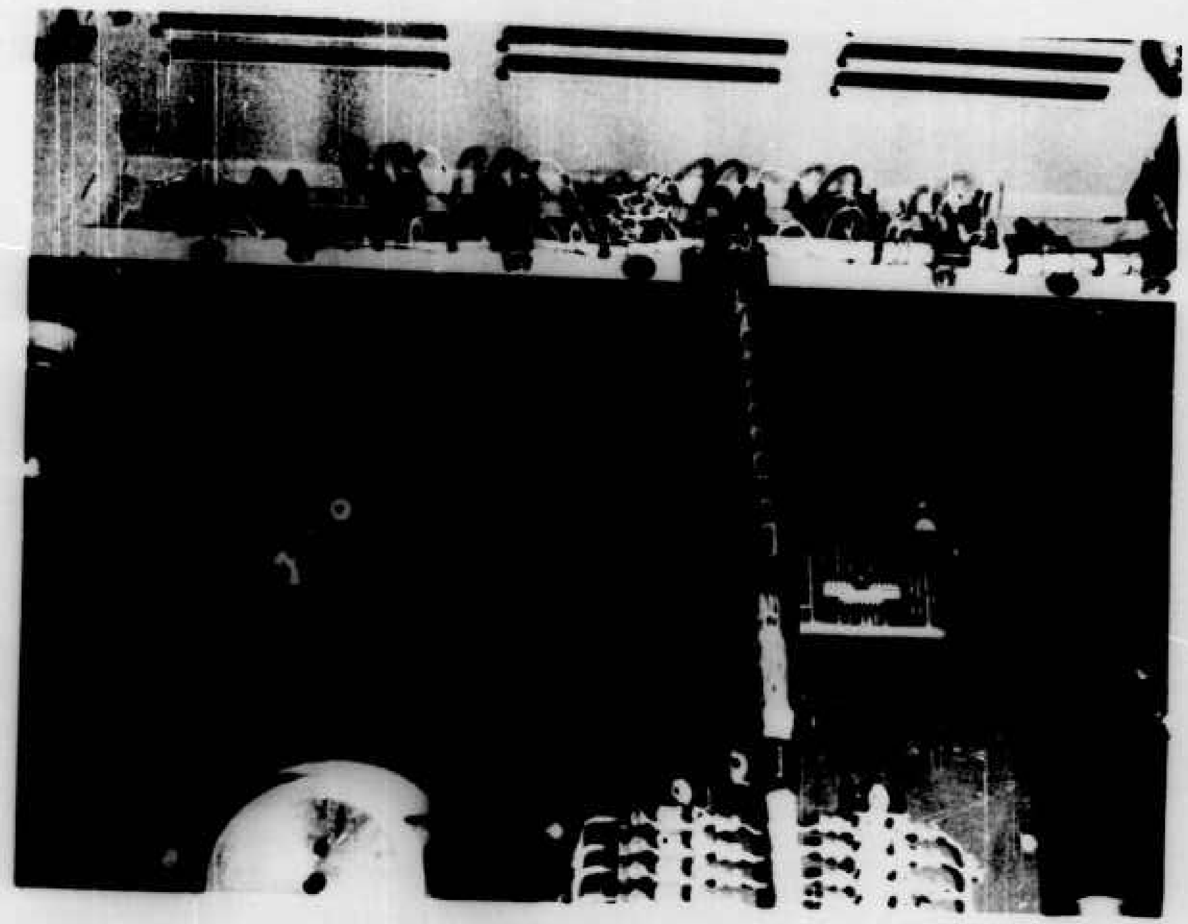
27199

Figure 20. AMDPS Data Recorder - Data Recorder Panel Front View (MOD)



27310

Figure 21. AMDPS Data Recorder – Data Recorder Panel Rear View (PRE-MOD)



27200

Figure 22. AMDPS Data Recorder – Data Recorder Panel Rear View (MOD)

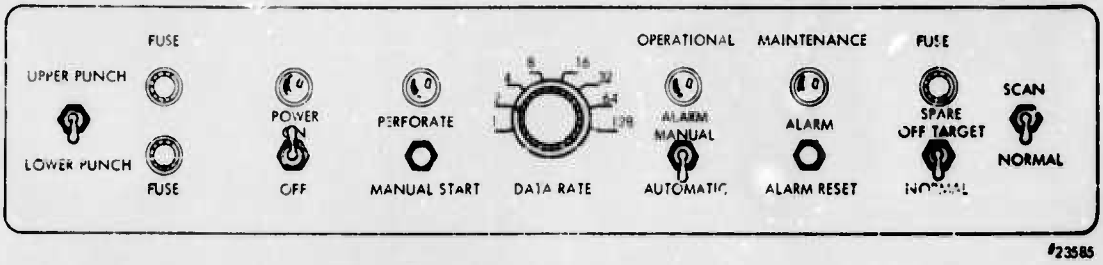
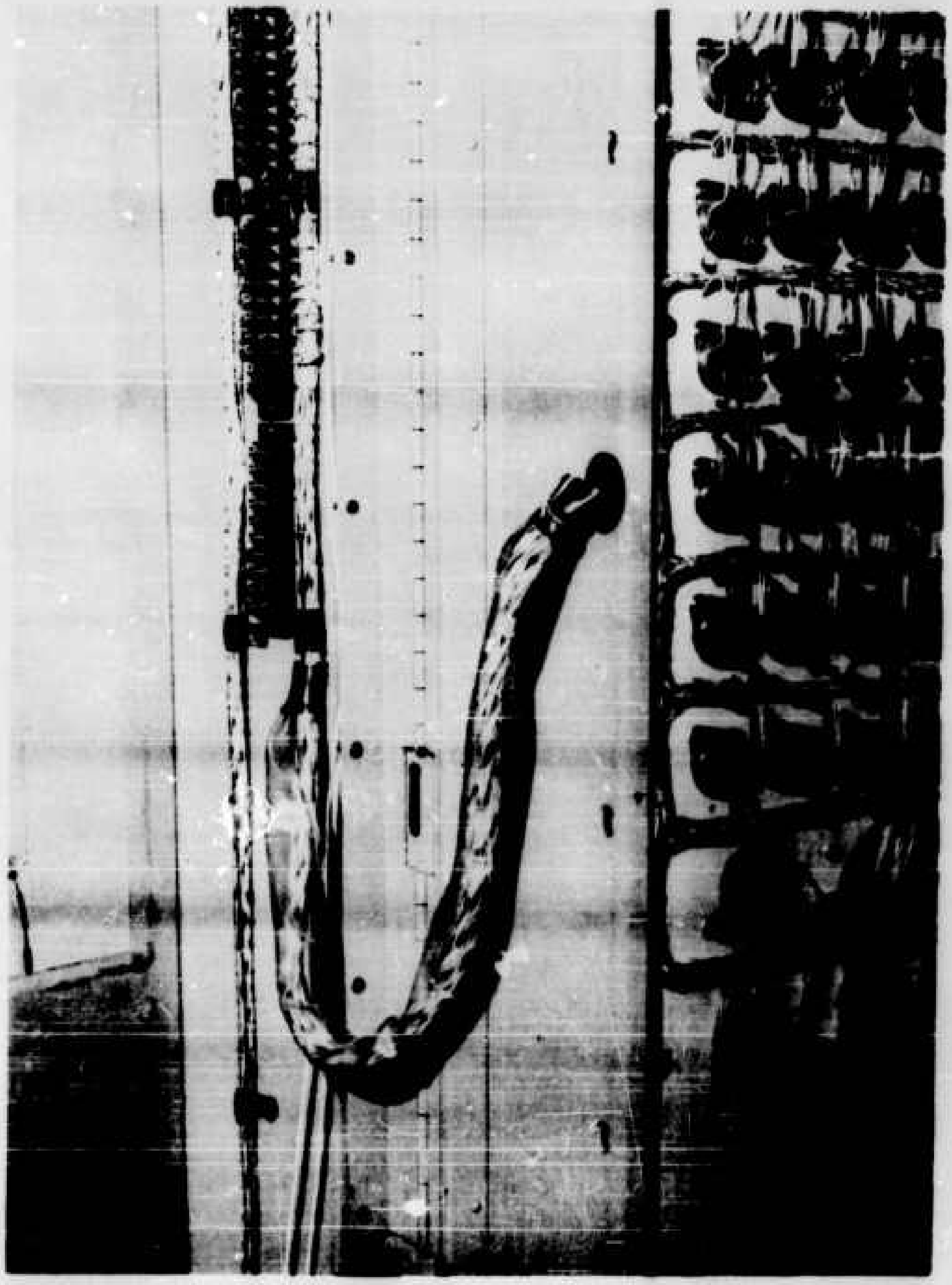
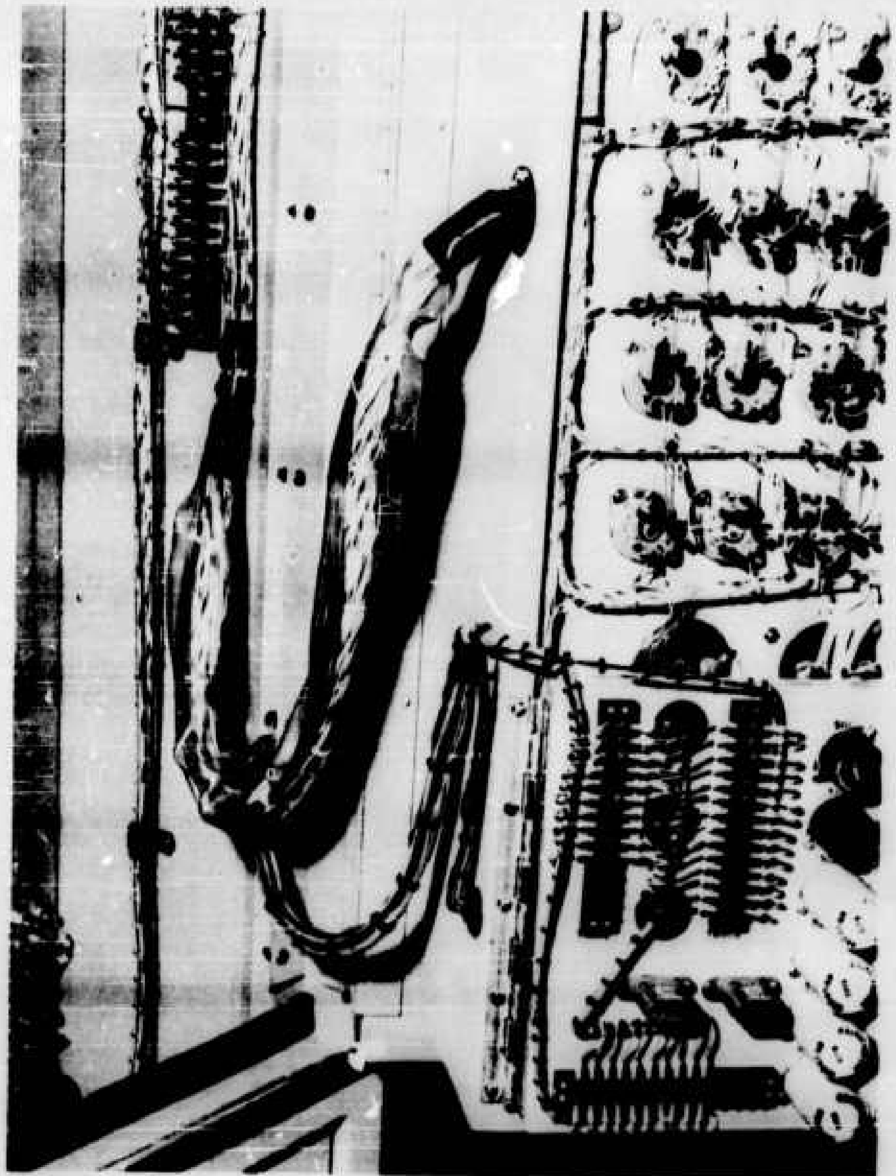


Figure 23. AMDPS Data Recorder - Data Recorder Panel Detailed Layout (MOD)



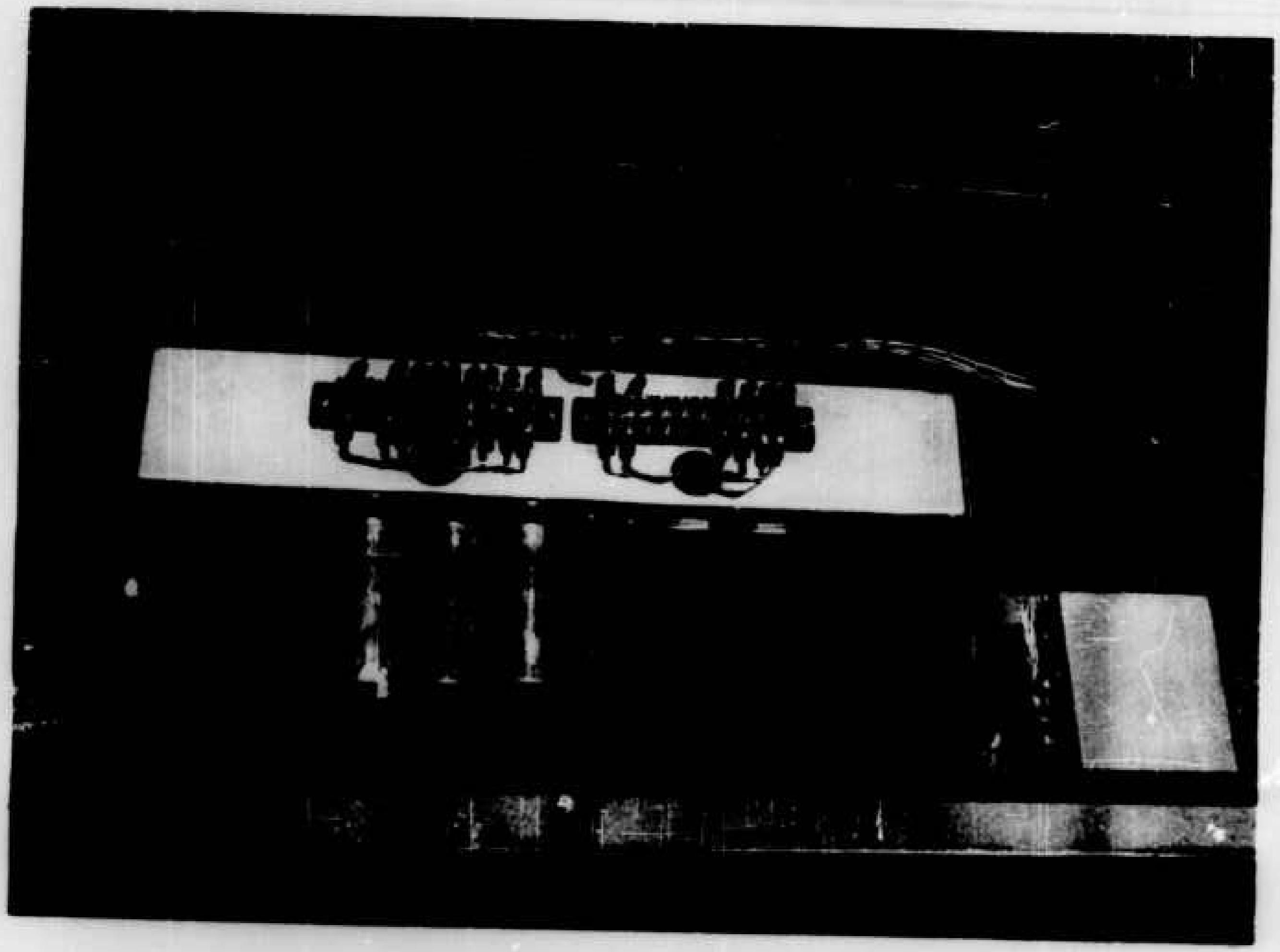
27311

Figure 24. AMDPS Recorder - Internal View (PRE-MOD)



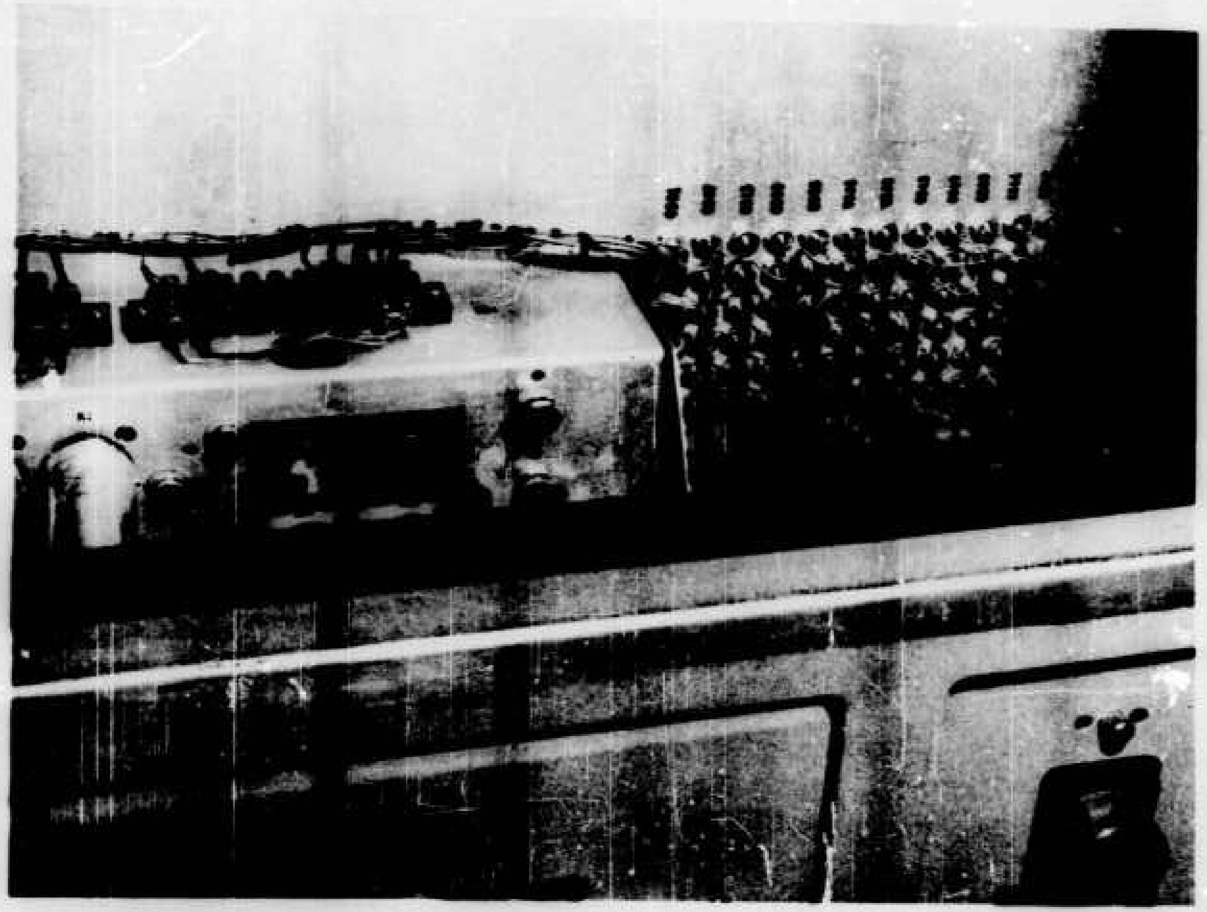
27201

Figure 25. AMDPS Data Recorder - Internal View (MOD)



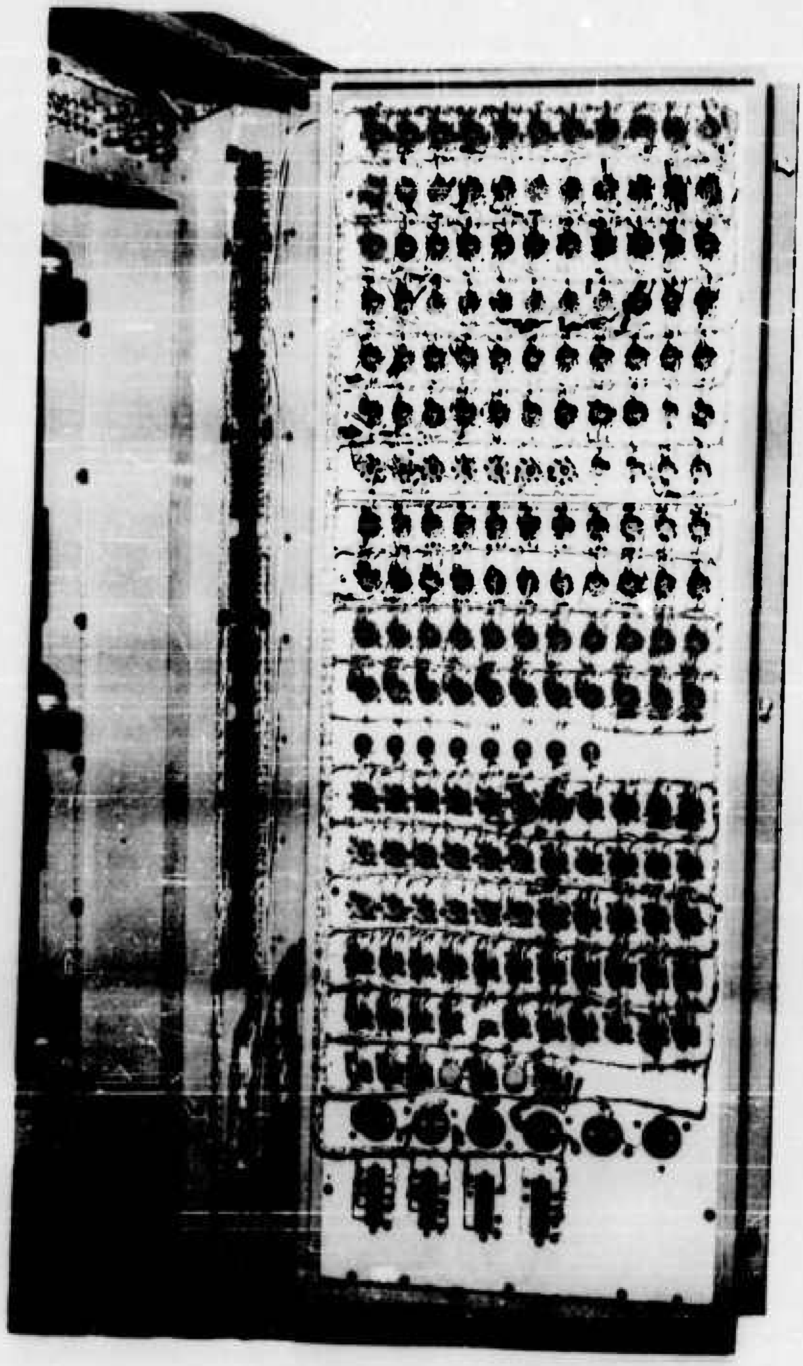
27312

Figure 26. AMDPS Data Recorder – Feedthrough Capacitor Panel (PRE-MOD)



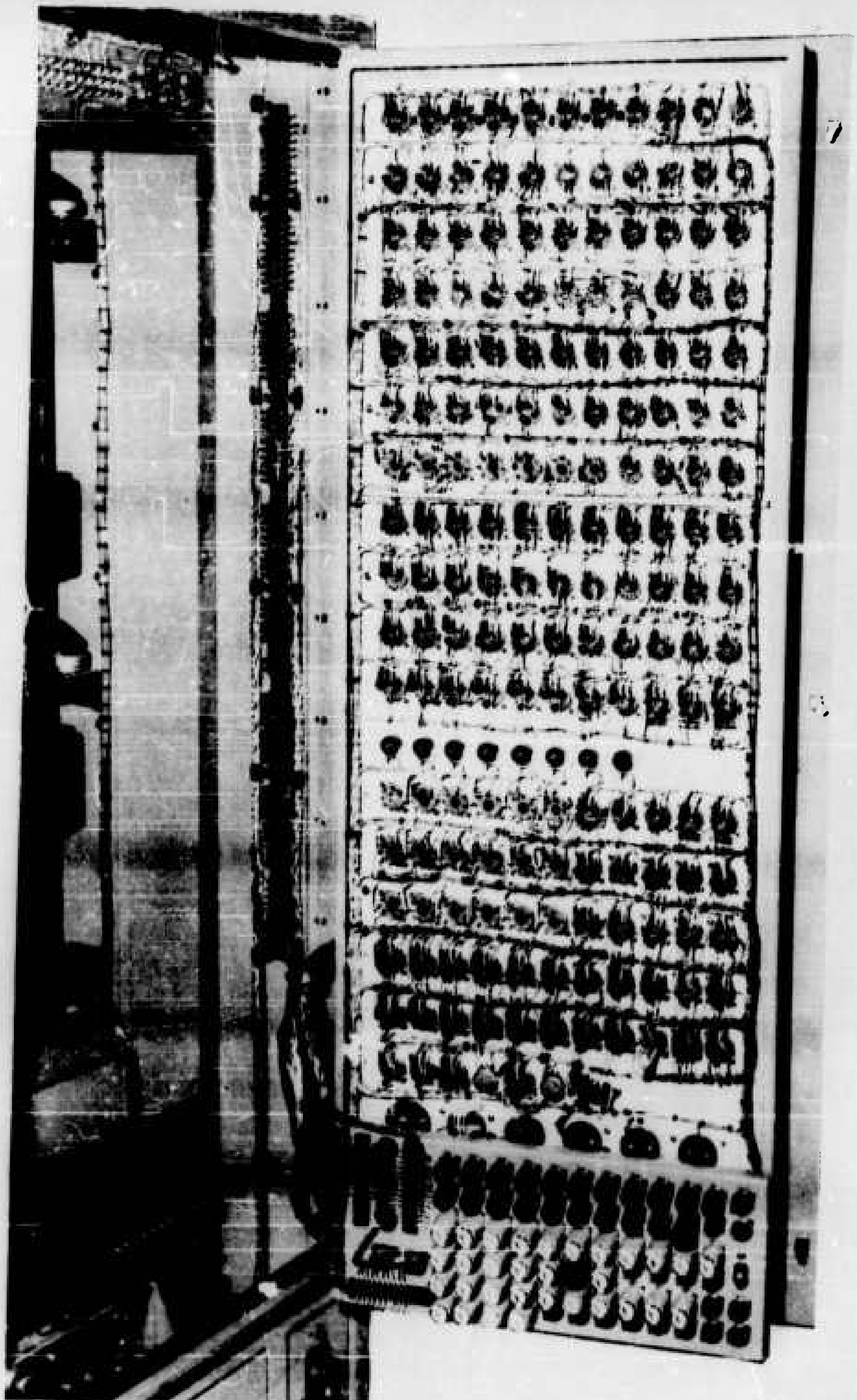
27202

Figure 27. AMDPS Data Recorder – Feedthrough Capacitors (MOD)



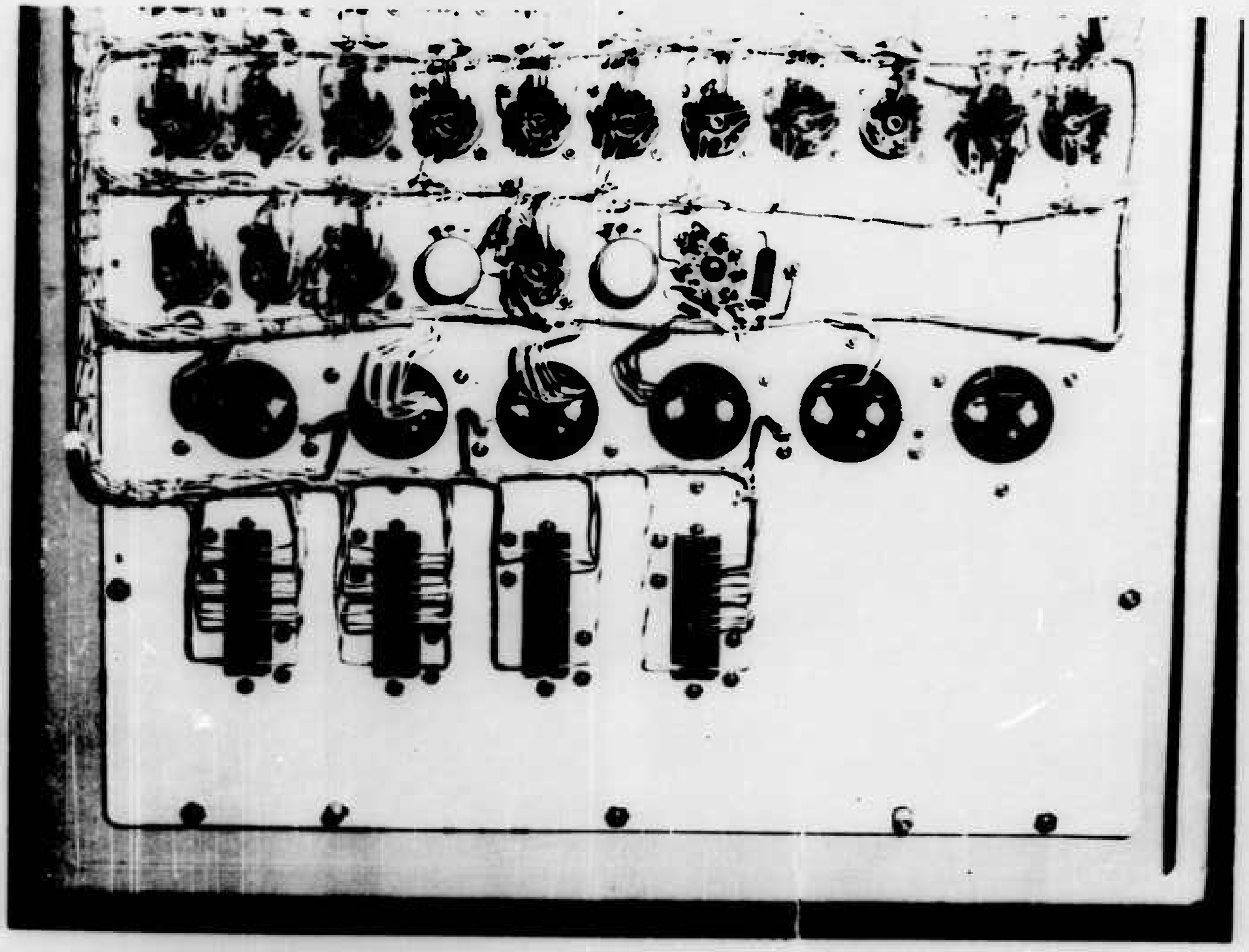
27313

Figure 28. AMDPS Data Recorder - Rear Door (PRE-MOD)



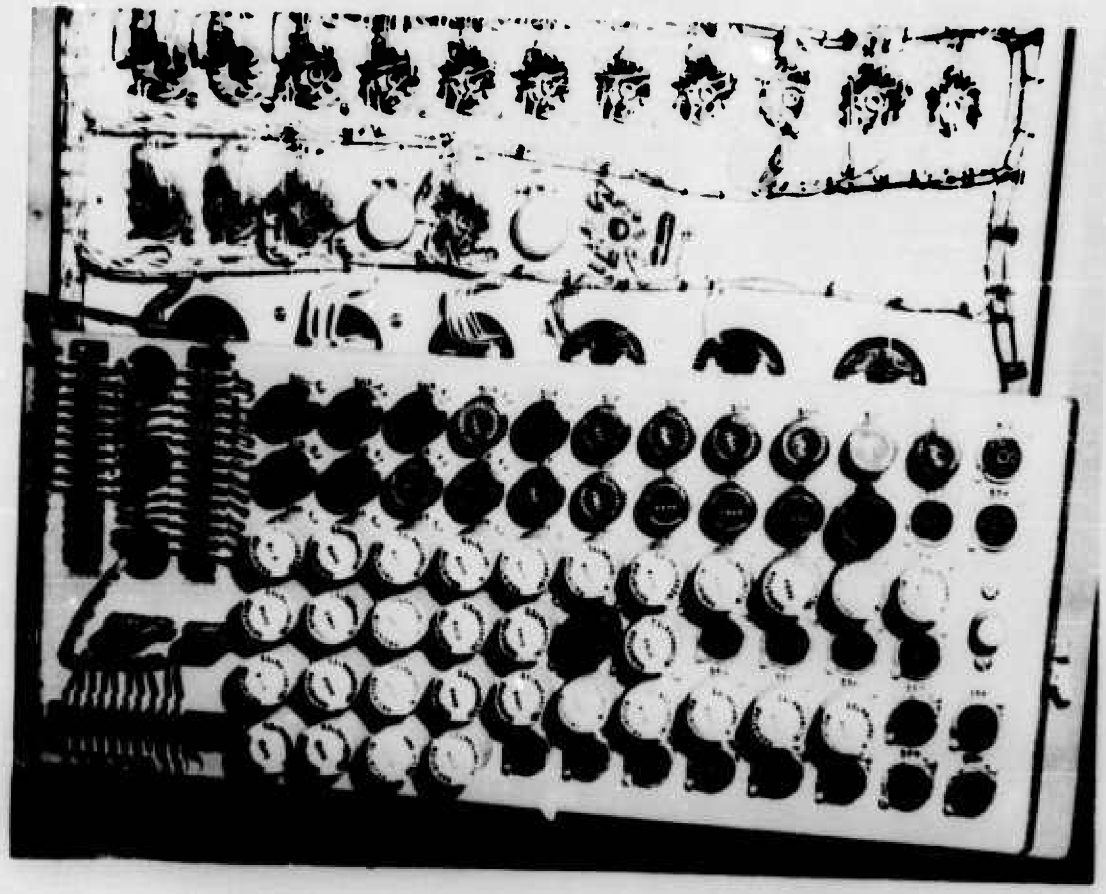
27203

Figure 29. AMDPS Data Recorder – Rear Door (MOD)



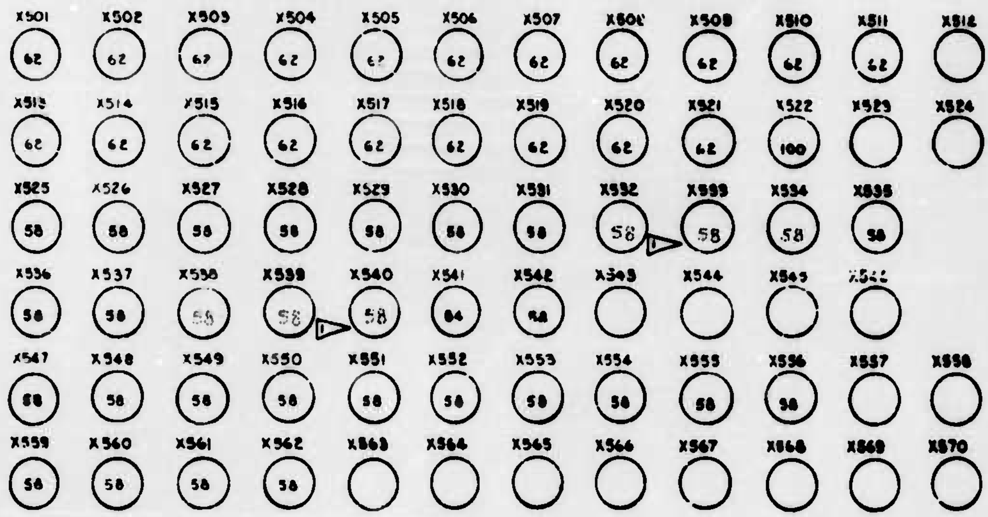
27314

Figure 30. AMDPS Data Recorder – Rear Door, Detail (PRE-MOD)



27204

Figure 31. AMDPS Data Recorder - Rear Door, Detail (MOD)

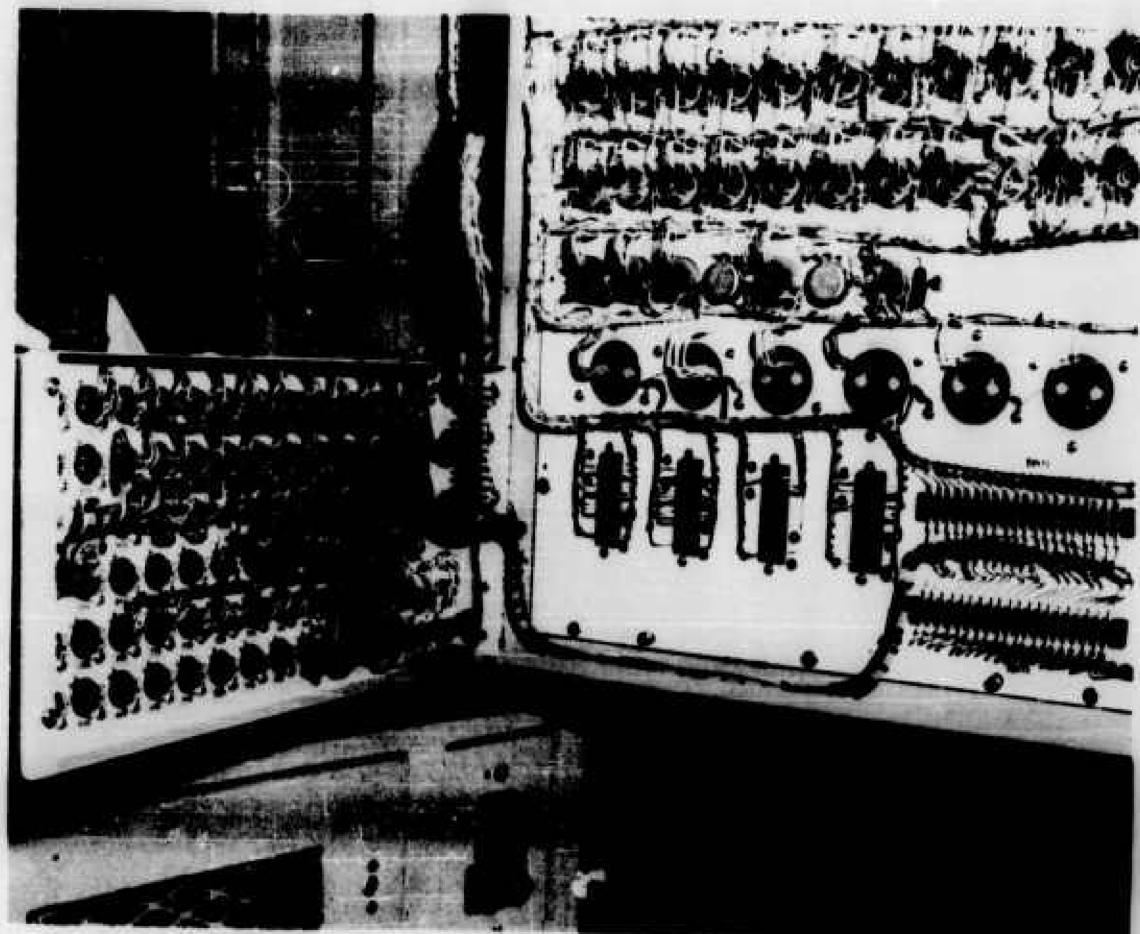


NOTES

1. DOTTED MODULE NUMBERS ARE OPTIONAL
2. NO. 62 - DC LEVEL SHIFTER & 2 INPUT GATE - COLOR BLACK
3. NO. 100 - SCHMITT TRIGGER - COLOR BLACK
4. NO. 84 - DUAL RELAY DRIVER - COLOR GREEN
5. NO. 58 - DUAL INPUT COINCIDENCE GATE - COLOR YELLOW

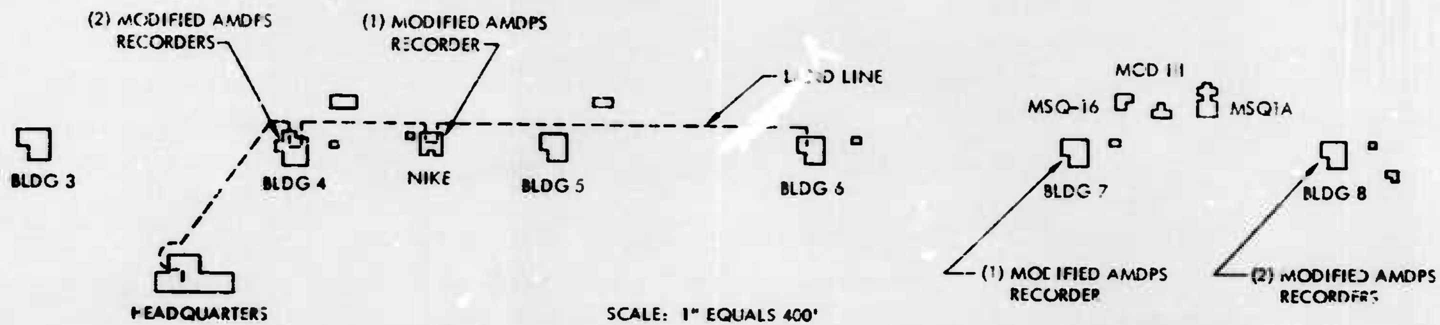
25793

Figure 32. AMDPS Data Recorder - Module Layout, Supplemental Chassis (MOD)



27205

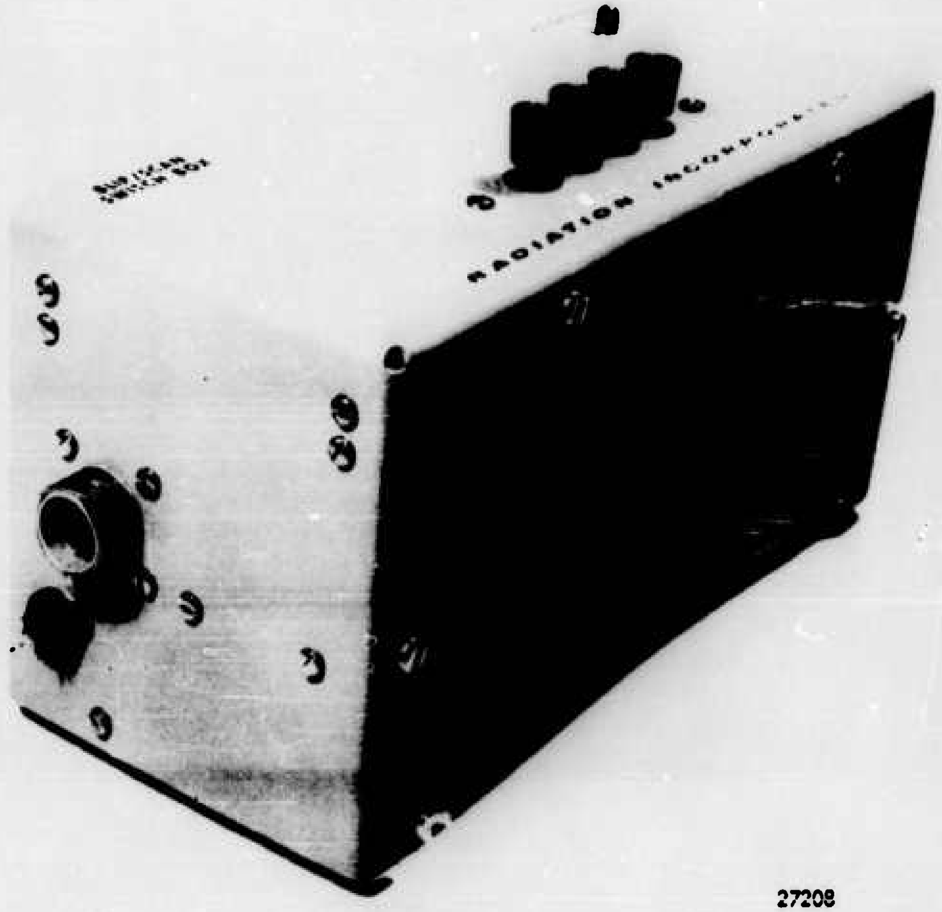
Figure 33. AMDPS Data Recorder - Lower Rear Door (MOD)



NOTE: BLIP/SCAN AND JAMMING EFFECTIVENESS SWITCH BOXES CAN BE USED IN ALL BUILDINGS CONTAINING MODIFIED AMDPS RECORDERS AND IN HEADQUARTERS

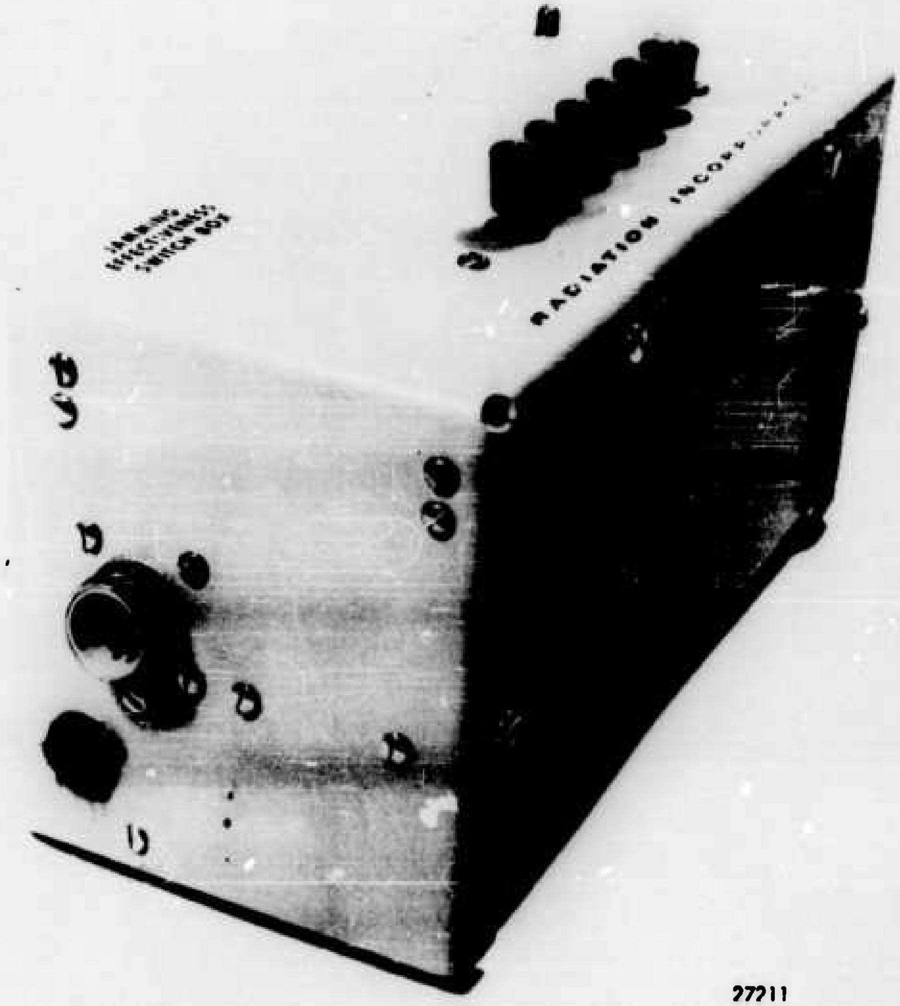
#25770

Figure 34. Modified AMDPS, Verona Site – Cable Runs



27208

Figure 35. Blip/Scan Switchbox - Three Quarter View (MOD)



27211

Figure 36. Jamming Effectiveness Switchbox - Three Quarter View (MOD)

one button can be depressed at any one time, and this button cannot be released by the operator. The depressed button will be released automatically after the information has been recorded by the AMDPS. This method has also made possible the distinction between a zero data condition and a NO data condition, see Figures 35 and 36.

2.2 Design Approach

2.2.1 Airborne System

The Airborne Time System, see Block Diagram 37 is an extension of the Time Signal Set AN/USQ-23(V). As previously explained, the purpose of the system is to visually display the time code generated from the Radiclock of Time Signal Set AN/USQ-23(V). The system also provides a parallel BCD output at the Airborne Time Decoder.

In the design of the system, the transmission of the time information over a standard radio link was the area of main concern. Development of the Airborne Units for aircraft environment was also dependent on ruggedized construction.

Radio transmission is plagued with many types of interference. The fault could be with the transmitter or the receiver, or any atmospheric disturbance. To minimize the possibility of introducing error into the system before the transmitter or after the receiver, a frequency shift keying system was used. Frequency shift modulating the transmitter was used over the method of modulating the transmitter directly with an ON/OFF tone burst code from the Time Signal Set because the immunity of the time signal to noise is better with frequency shift key modulation than with ON/OFF tone burst modulation. Only the pre-transmitted and post received signals are being considered. The radio link was fixed and at the time of equipment design, a minimum of effort was spent in radio transmission problems. The contract stated that the Air Force would supply the radio link. Immunity to noise at the outp it is extremely important due to the high interference noise level sometimes present around the particular receivers used for the time information radio link.

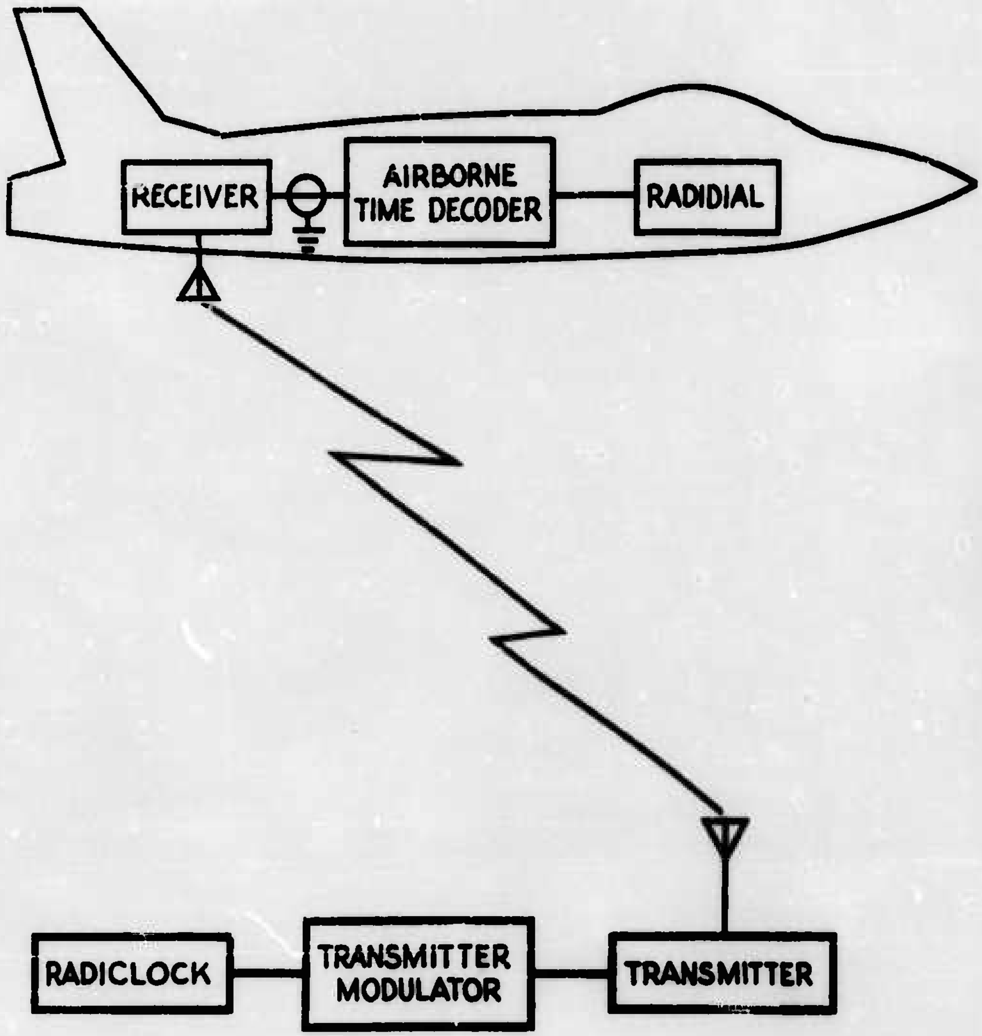
A survey of all the available methods of modulation pointed to the use of the frequency shift key modulation. A 3 to 5db gain in noise immunity is realized with use of frequency shift key modulation over standard AM modulation. The mathematical proof is beyond the scope of this report. The following references will help in arriving at the improved noise immunity figure:*

With the use of the frequency shift key modulation, oscillator stability becomes important. The input filter to the Airborne Time Decoder has a pass band of 300 cps. The band pass of the filter is kept as narrow as possible to provide maximum rejection of noise outside the desired frequency band. To keep the

* Wier, J.M. Digital Data Communication Techniques, Proceedings of the IRE, January 1961, Hund, A. Frequency Modulation, Chapter I, Section B, Middleton, D. Statistical Communication Theory Chapter 15, Section 5 - 7.

band width in the Airborne Time Decoder discriminator narrow, the frequency shift oscillator must be stable. An LC oscillator was used as the frequency shift oscillator. Oscillator stability is obtained by matching the change in inductance of the toriodal inductor with temperature by using capacitor which changes with temperature in the opposite direction. Polysterene capacitors exhibit the correct characteristics for compensating the change in inductance of toriods with temperature. The results of temperature tests of the frequency shift oscillator used in the Transmitter Modulator are seen in Figures 38 and 39.

It has already been explained that the Airborne Time Decoder has two modes of operation; the slave mode where the incoming time signal is decoded and stored and the clock mode. Even with preccutions taken to select the best method of data transmission, link malfunction or range limitations due to distance or line of sight could cause false or no time information. There are several methods which could be used to recognize a false code or lack of code, and then cause the Airborne Time Decoder to reject the false code and switch from a passive storage unit to an active time generator. To make the recognition circuitry fool-proof, the Airborne Time Decoder would require a considerable addition of circuitry with some complication. Since complexity and additional circuitry decreases reliability a compromise was made to minimize circuit additions. The required ability to recognize most false codes or no-time information at the Airborne Time Decoder has been retained. The time code format will be reviewed to determine a method for recognizing false codes and no code. The video code after the discriminator in the Airborne Time Decoder is seen in Figure 40 as twenty-one digits. The sync digit is 32 milliseconds in duration; the "Yes" digits are 16 milliseconds in duration and the "No" digits are 8 milliseconds in duration. The "Yes" and "No" digits do not remain in the same time relationship, from code to code, but the sync digit is always the first digit in each code. The pulse width of the sync bit is one unique characteristic, and the 21 code digits are a second unique condition. The two fixed parameters of the time code will be used to recognize the absence of code signal and false codes. The twenty-one code digits are counted and the sync pulse width is recognized. If any of the code digits are missing, or there are greater than 21 code digits between sync digits, the code entered in the input shift register is not transferred to the output storage register, and a crystal controlled clock pulse is used to progress the storage register. The storage register is connected as a BCD rime of day counter. If no sync pulse is recognized 1.066 seconds after the previous recognized sync pulse, no data is transferred from the input shift register to the storage register and a crystal controlled clock pulse is used to progress the last good time code at a one second rate. The logic for false code recognition is seen in Figure 41. As previously mentioned, the Airborne Time Decoder was ruggedized for aircraft environment. Beside an aircraft environment, the Airborne Time Decoder will be subjected to high levels of audio and RF interference. The Airborne Time Decoder is mounted on a standard shock mount base. The plug-in modules are held in place by covers. The covers are attached to each swingout card. The enclosure is welded to minimize RF interference. The cover of the Airborne Time Decoder is hinged and fits into a recessed well.



#23591

Figure 37. Airborne Time Display System

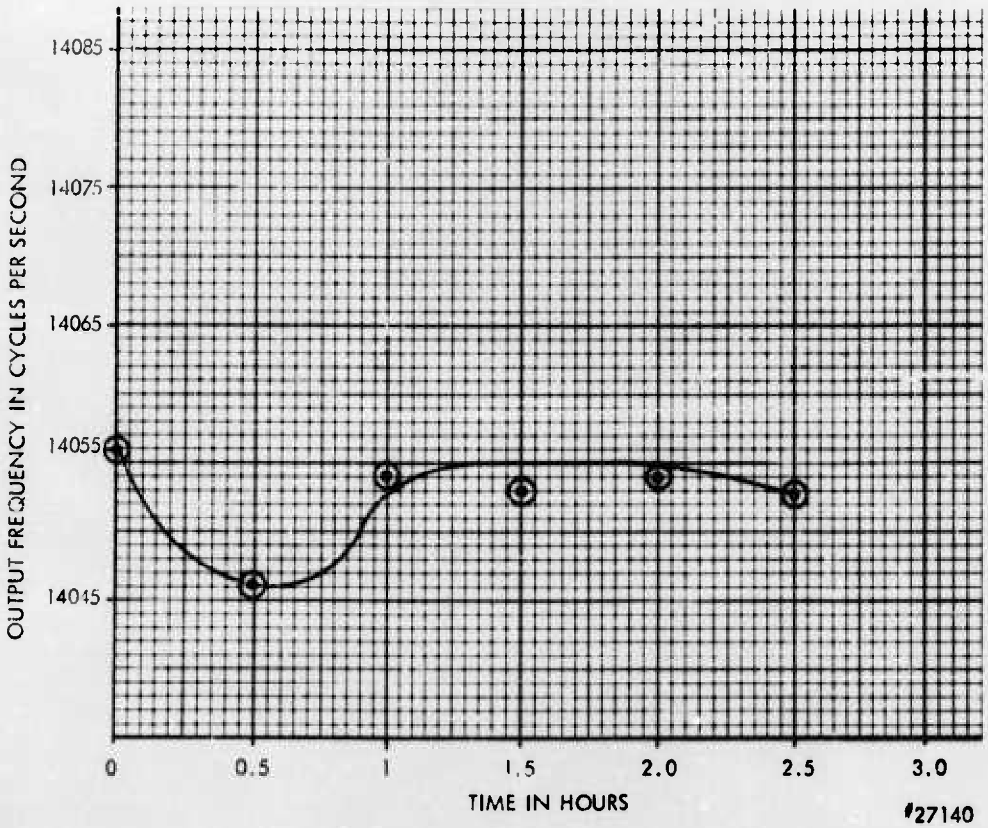


Figure 38. Plot of Frequency vs Time for Frequency Shift Oscillator at -10°C

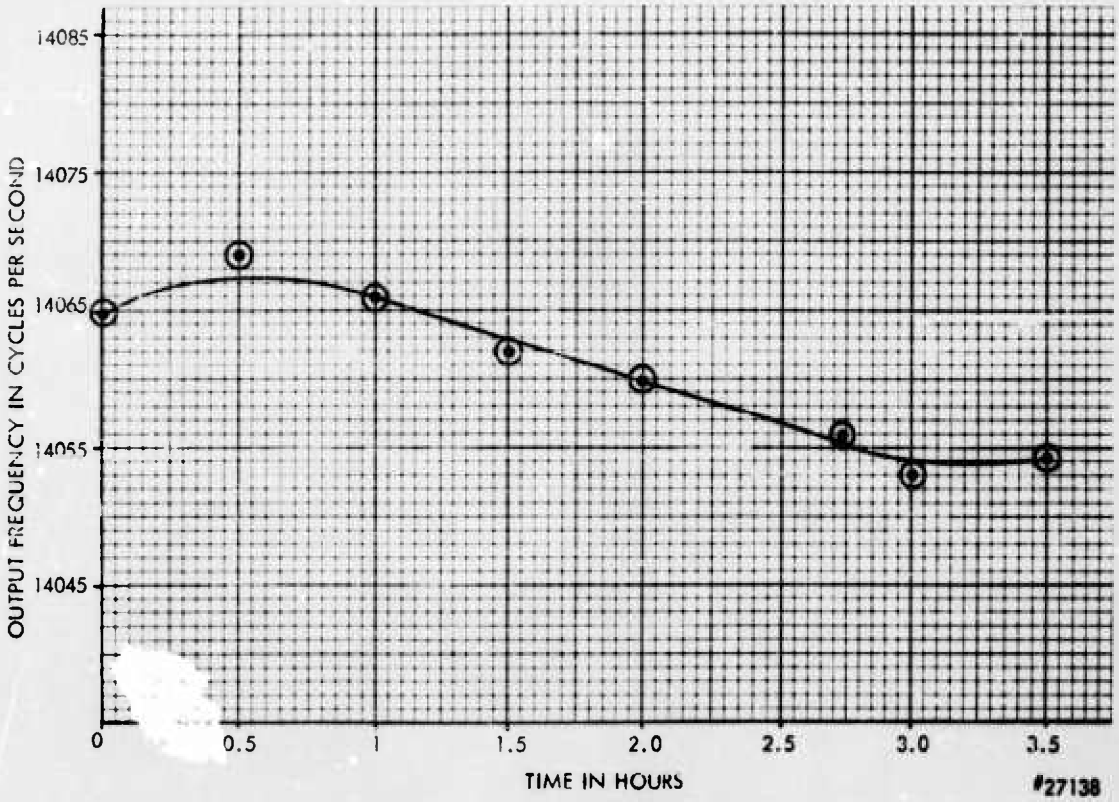
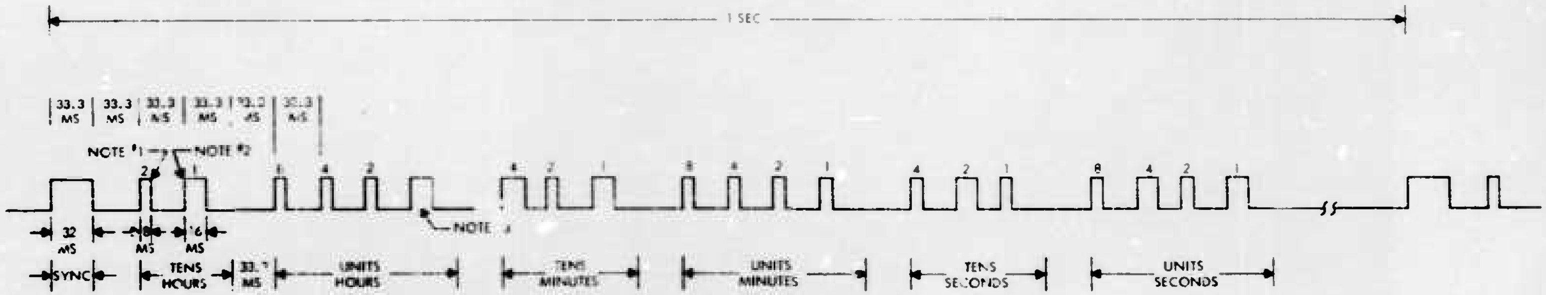


Figure 39. Plot of Frequency vs Time for Frequency Shift Oscillator at +55°C



THE ABOVE CODE READS 11 HOURS: 50 MINUTES: 25 SECONDS

NOTE #1 8 MS DIGIT INDICATES NO BIT

NOTE #2 16 MS DIGIT INDICATES YES BIT

NOTE #3 CARRIER IS 1000 CPS

#25567

Figure 40. Video Time Code Format

Silver-plated finger stock is attached to the cover to match the mating parts of the enclosure for RF interference control.

One output of the Airborne Time Decoder is a decimal output used to control Nixie readout tubes. The other output is the parallel BCD time code. The readout unit, Airborne Radidial, is a ruggedized version of the Radidial used with Time Signal Set AN/USQ-23(V).

A brief summary of factors influencing the design of the Airborne Time Display System will be given. The selection of the frequency shift key modulation of the transmitter, to improve noise immunity, set frequency stability requirements for the frequency shift oscillator in the Transmitter Modulator. Because radio transmission is not 100% reliable, recognition of wrong or no incoming time codes at the Airborne Time Decoder is necessary. Because the Airborne Time Decoder and Airborne Radidial are subject to aircraft environment, both units are ruggedized with respect to shock, vibration, temperature, and RF interference.

2.2.2 Radar Display System

2.2.2.1 Pick-Off Unit

The purpose of the Pick-Off Unit is to receive radar range and azimuth information and to convert and transmit this information to various locations.

The range and azimuth information exists in mechanical and electrical form in the servo system of the radar. It would, therefore, be possible to attach code wheels to the servo system of the radar or to parallel the electrical output of the servo system with sufficient buffering to obtain the desired radar information. The radar information is also available in the Track Radar Evaluator in BCD form. It was decided to pick the radar information from the Track Radar Evaluator. This decision was made since picking the information from the Track Radar Evaluator would be the least expensive method. The two main disadvantages are that the Track Evaluator must be turned on and operating properly for the Pick-Off Unit to function. The contracting authorities and Radiation Incorporated felt that the savings in cost was the determining factor in the method of pick-off.

The radar information transmission method is the same as that used by the Radiclodk of Time Signal Set AN/USQ-23(V). See Figure 42, Pick-off Unit Code Format. This decision was made for the following reasons:

1. The PWM tone burst code has proven successful in the Time Signal Set AN/USQ-23(V).

2. The necessary co-axial land line for code transmission already existed.

3. The land line has sufficient bandwidth to allow several more carrier frequencies.

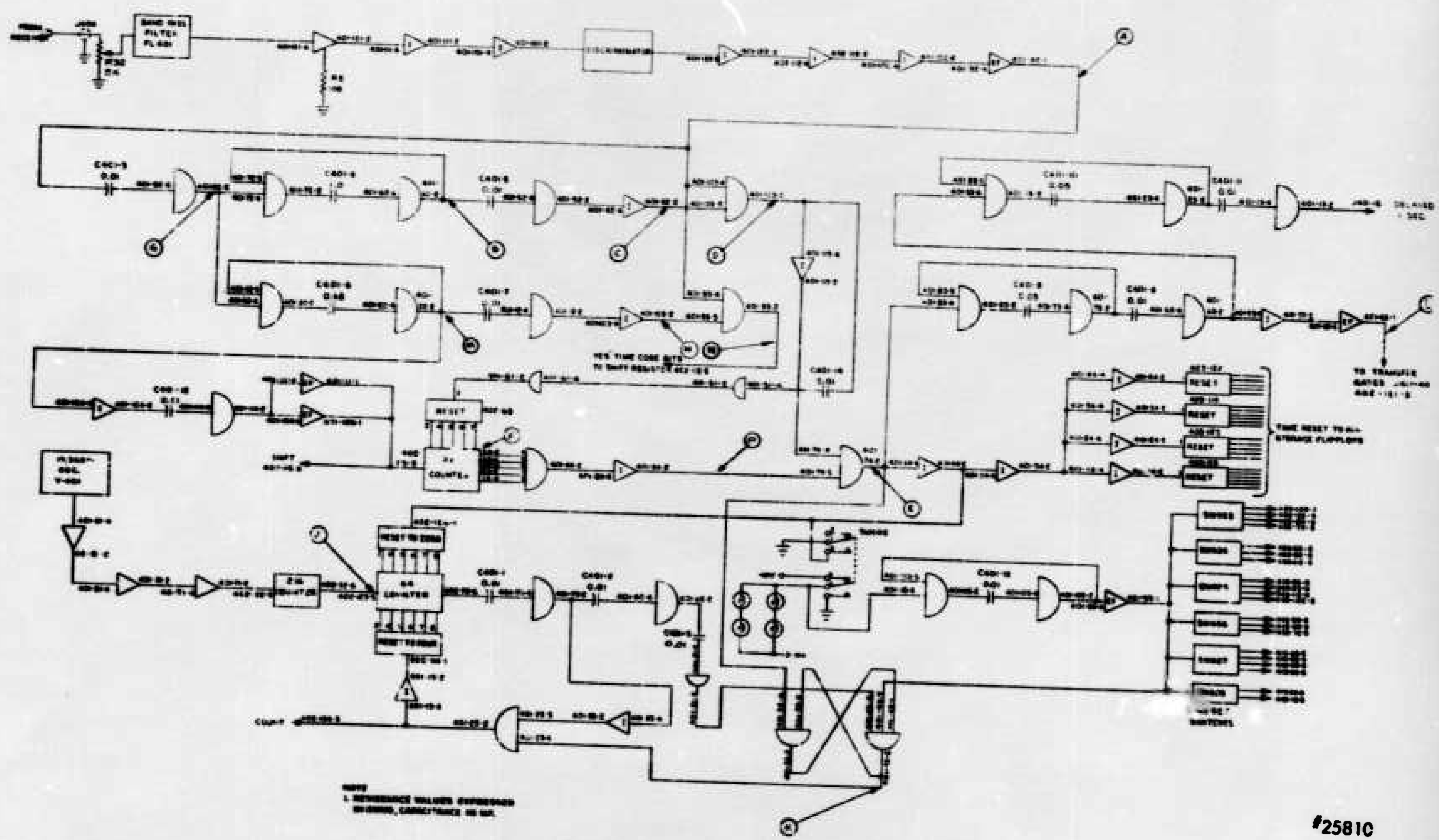
Carriers of 14.5KC and 12KC were chosen for the MSQ-1A and MOD III radars, respectively.

The Pick-Off Unit has a self-contained proven power supply, illustrated in Figure 43. The power supply is short-circuit and overload protected. Both the +10 and -10 volts can be short-circuited for prolonged periods of time, and no damage to the power supplies will result. This is deemed to be a very desirable maintenance feature, since accidental shorts by maintenance personnel do not require interruption of work to replace fuses or find and replace damaged components.

The digital circuitry is mounted on swingout aluminum boards. The circuit modules are readily accessible when trouble-shooting is required. All signal and power points are available at the module socket.

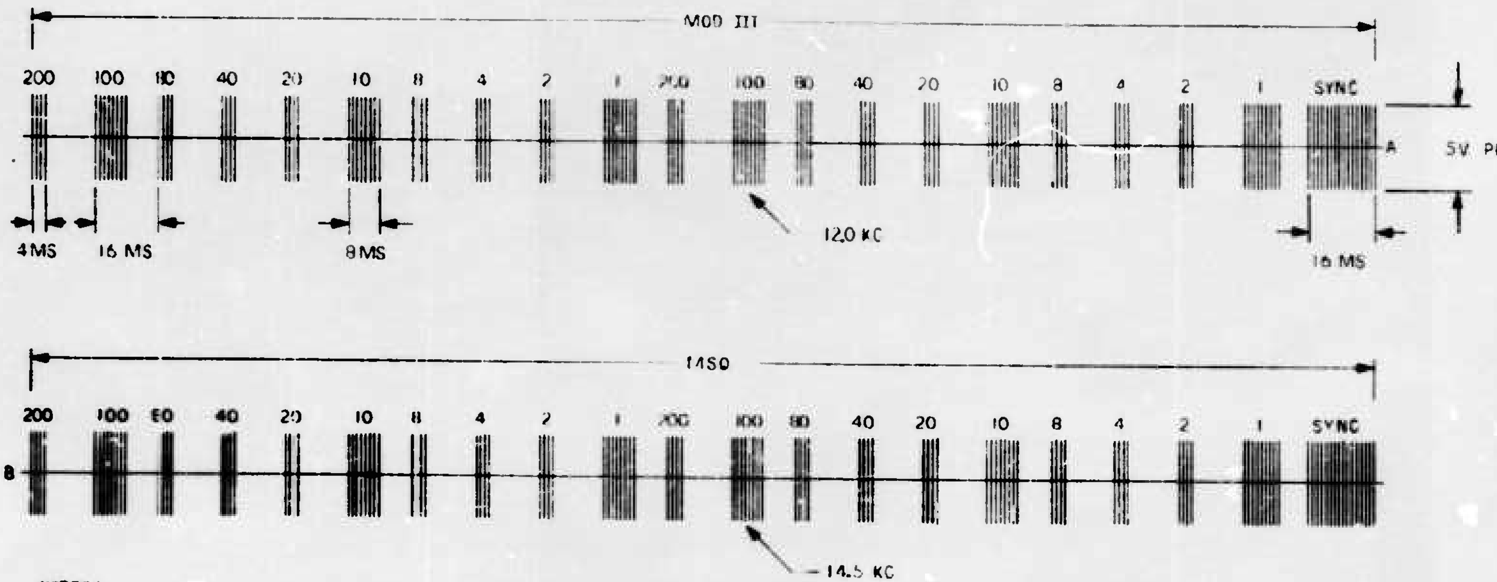
The only major troubles encountered in design and operational checkout of the Pick-Off Unit were problems involving the interface of the Pick-Off Unit with the Track Radar Evaluator. The first problem involved timing between the Pick-Off Unit and the Track Radar Evaluator. Due to insufficient detail concerning the timing of the Track Radar Evaluator, the internal timing pulses in the Pick-Off Unit used to enable the input gates were not correct, and the data gated into the Pick-Off Unit was not the desired information. To correct for the mismatch in timing, a few minor changes were made in the timing electronics of the Pick-Off Unit.

The other difficulty encountered was also a timing problem. The Track Radar Evaluator is mechanically driven by a synchronous motor. Attached to the housing of the synchronous motor and operated by a cam on the shaft of the motor is a set of contacts that derive the basic time standard of the Track Radar Evaluator and the Pick-Off Unit. Since this method of timing is mechanical, the disadvantages of mechanical timing are present. One disadvantage is that the contacts become pitted or uneven and generate spurious or false timing marks. These false timing marks created an improper timing sequence in the Pick-Off Unit which resulted in erroneous operation. To eliminate the false or spurious time marks, the contacts were cleaned several times. This is by no means a permanent solution. At the time of installation the maintenance personnel at Verona were replacing the timing contacts with a reference generator to be driven by the synchronous motor. The reference generator is a good solution and should eliminate all spurious or false time marks that are due to the timing contacts.



#25810

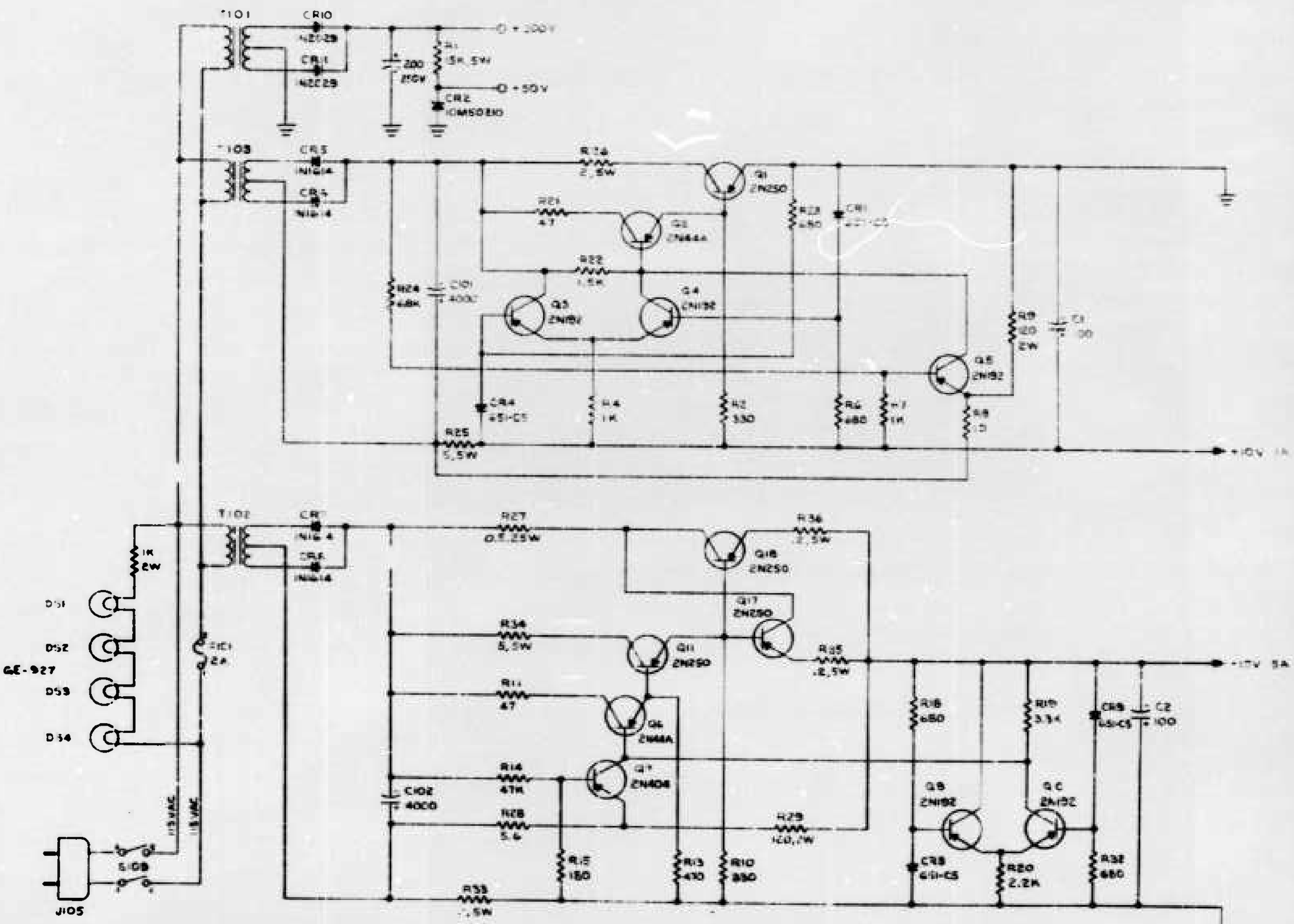
Figure 41. Logic Diagram – Synchronizer – Airborne Time Decoder



NOTES:
1. 32 MS DELAY BETWEEN
POINT A & B.

#25836

Figure 42. Code Format - Pickoff Unit

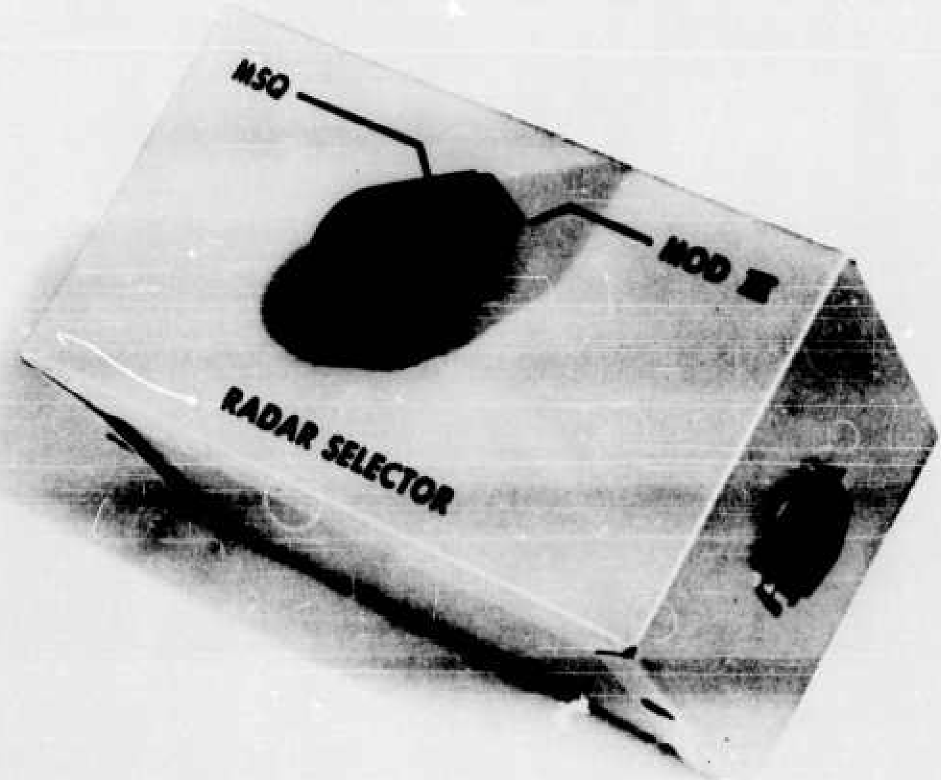


NOTES:

1. UNLESS OTHERWISE SPECIFIED ALL RESISTANCE VALUES ARE EXPRESSED IN OHMS 1/4W ±5%; ALL CAPACITANCE VALUES ARE IN UUF.
2. 200V & 50V POWER SUPPLY ARE ABSENT IN THE PICK OFF UNIT.
3. CONTROL UNIT 100 SERIES. PICK OFF UNIT 200 SERIES.

Figure 43. Schematic – Power Supply

27306



27315

Figure 44. Ra.ar Selector Switch

2.2.2.2 Control Unit

The Control Unit, Figure 11 is designed to use standard digital circuit modules. The function of this unit is to demodulate and recognize the serial radar code transmitted over the land line by the Pick-Off Unit. When the radar code is recognized, the radar range and azimuth is stored for one second for visual display by the Decimal Readout Units. A relay and two band-pass filters on the front end of the control unit determines which radar data is received. The relay is controlled by an external switch (Radar Selector Switch). Figure 44. One filter is 14.5KC and the other is 12KC for MSQ-1A and MOD III radar information, respectively.

The Control Unit has a self-contained power supply identical to the power supply in the Pick-Off Unit with the exception of an additional 200 volt and 50 volt power supply. The 200 volt and 50 volt power supply are used for the Nixie drivers and Nixie tubes.

The majority of the circuitry is mounted on swingout aluminum boards. The circuit modules are readily accessible when trouble shooting is required. All signal and power points are available at the module sockets.

The Control Unit can be used to supply signal and power to a maximum of ten Decimal Readout Units. Parallel BCD signals which represent the radar range and azimuth are also available as an output. This output may be used to drive oscillographic recorders, etc.

No particular problem was encountered in the design, construction or installation of the Control Unit. Since the Time Signal Set AN/USQ-23(V) is similar in nature most problems were foreseen and considered in advance.

2.2.2.3 Decimal Readout Unit

The Decimal Readout Unit is a visual, remote display unit. It consists of a chassis for six nixie tubes and two indicator lamps, Figure 13. The Nixie tubes are operated by control signals and power from the Control Unit. The Nixie tubes display the radar range and azimuth and the indicator lamps indicate the radar from which data is being displayed.

2.2.3 AMDPS Modification

The design philosophy utilized in the AMDPS Modifications was chiefly determined by four factors; space, cost, maintenance, and field installation. Final decisions were reached only after a thorough review of all factors and after logical compromises had been determined.

Space was the first problem to be considered. The need to provide additional circuitry to perform the added features was apparent, and the problem under consideration was to determine whether this additional circuitry should be mounted in another unit external to the recorder, or if the additional circuitry could be contained inside the RF seal of the AMDPS Recorder. The result was additional circuitry mounted inside the recorder where space was available, since two seperate units could easily be seperated and, therefore, more difficult to maintain. After a complete study of available space inside the recorder was considered, it was decided that some additional circuitry could utilize space vacated by the existing circuitry eliminated in the modification; also, additional mounting space was provided by a supplement chassis mounted on the bottom of the door. Space for connectors was found on top of the Recorder and space for additional RF feed-through capacitors was found below the RF Shield Panel.

Module fabrication was the next problem to be decided. A small module featuring low power requirements and low cost, led to the decision of the throw-away type of encapsulated module, except where the existing Vitro modules used in the AMDPS was deemed necessary and more convenient. Four different types of modules were sufficient to meet the requirements needed for the additional circuitry. These circuits are discussed in detail inthe Instruction Manual.

Fabrication of wiring harnesses to be used inside the Data Recorders, assembling of components, and soldering of RF feed-through capacitors and connectors were accomplished at the Radiation Incorporated plant to minimize the amount of field installation needed at the Verona Site.

2.3 System Description and Operation

2.3.1 Airborne System

This section will present a discussion of the areas of difficulty encountered in the design, fabrication, checkout and installations of the Airborne System. No attempt is made to present a complete theory of operation. A complete theory of operation is given in the Instruction Manual.

In general, the design, fabrication, checkout and installation of the Transmitter Modulator, two Airborne Time Decoders and two Airborne Radidials was done with very few difficulties.

The internal heat generated in the Airborne Time Decoder was one problem which caused some trouble. The unit is sealed tight to eliminate RF interference. The unit is compact to keep the size down for use in aircraft. The circuitry associated with the power supply regulators was affected by the internal heat. The heat in this area was the highest due to the power transformer.

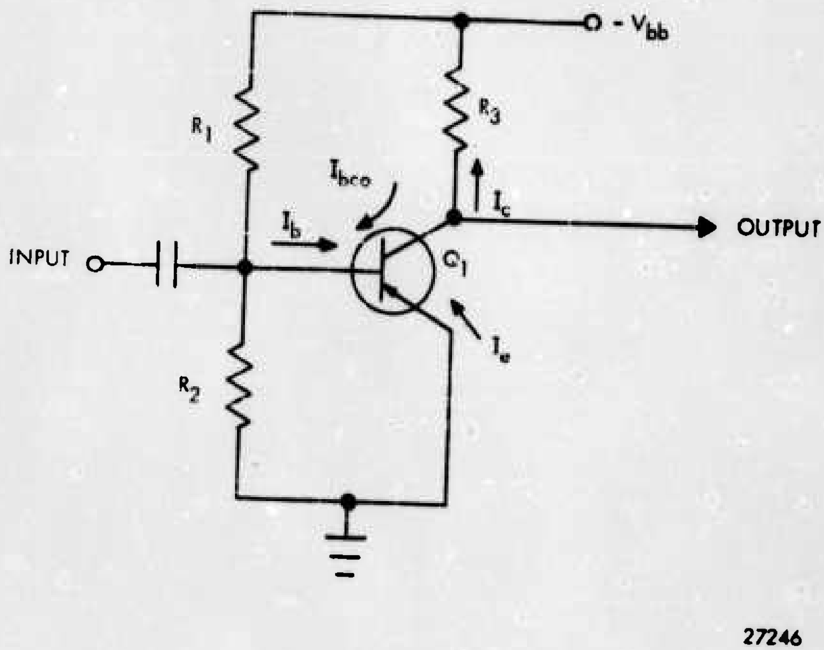


Figure 45. Grounded Emitter Amplifier

It is seen that the output voltage of a grounded emitter amplifier, see Figure 45, is a function of input current I_b.

$$\text{Where } V_0 = I_c R_3$$
$$V_0 = I_b R_3 - V_{bb}$$

If R_1 and R_2 are picked to give a quiescent bias current of 100 microamps then the output voltage is,

$$V_0 = V_{bb} + 50 \times 100 \times 10^{-6} \text{ amps} \times R_3$$

$$\text{If } V_{bb} = -10 \text{ volts and } R_3 - 1000 \text{ ohms then,}$$
$$V_0 = -10 \text{ volts} + 5 \text{ volts}$$
$$V_0 = -5 \text{ volts}$$

It is seen that if I_b changes by + 100 microamps, the output voltage will change + 5 volts when the temperature is 25°C. An average I_{bco} for a 2N404 is 5 microamperes at 25°C. In the above calculation I_{cbo} has not been accounted for because at 25°C I_{bco} is low. It can be seen that 5 microamps out of 100 microamps is a small percentage error and can be neglected. At 55°C, the effect of I_{bco} cannot be neglected because as the temperature increases for a germanium transistor the leakage current I_{bco} of the transistors increases. A rule of thumb for the increased I_{bco} with temperature is that for a 10°C rise in temperature above 25°C, the I_{bco} doubles. It is seen that if a germanium transistor with a leakage current of 5 microamps at 25°C, the same transistor will have a leakage current I_{bco} of 40 microamps at 55°C. To see what effect temperature will have in the circuit operation, the following example will be given. Some basic equations relating base current, collector current and emitter current will be given. A simple grounded emitter amplifier, see Figure 45 will be used.

$$I_c + I_b + i_{bco} = I_e$$
$$\beta I_b = I_c$$

Where B is the current gain of the transistor. For this case, a 2N404 will be used where the average B is 50. I_{bco} is 40 microamps at 55°C. This is an appreciable change from the room temperature value, and this factor must be considered. In an AC amplifier, the maximum gain is reduced by 40 parts or about 40% to correct for the quiescent operating variation when the temperature changes from 25°C to 55°C.

In the initial design of the Airborne Time Decoder, temperature rise inside the Airborne Time Decoder from room temperature was assumed to be 10°C. For an outside temperature variation of ± 25°C from an ambient temperature of 25°C, the maximum internal temperature around the power supply regulator was calculated to be 60°C. All circuitry in this area was designed to operate properly at 60°C. Unfortunately, the internal heat rise was closer to 20 to 25°C. With an outside ambient temperature of 50°C, the internal temperature was 70°C to 75°C. The power transformer heat rise was considerable greater than that calculated and resulted in marginal operation of circuitry in close vicinity to the power transformer. The internal temperature in other areas of the Airborne Time Decoder was only 70°C to 12°C above outside ambient, and no marginal operation was encountered. The circuitry in the area around the power transformer was redesigned and no marginal operation was seen.

Only one other major difficulty occurred. When the output of a radio receiver was connected to input of the Airborne Time Decoder, the input to the Airborne Time Decoder was saturated. The maximum input level was designed at 10 volts peak to peak. The output from the receiver was in the order of 80 volts peak to peak. An input attenuator was added to correct this difficulty. A variable attenuator was used to accomodate a wide range of input voltage levels.

2.3.2 Radar Display System

A complete theory of operation of the Radar Display System is contained in the Instruction Manual and, therefore, will not be presented here. A brief system description including operation and installation will be discussed.

Refer to Figure 46 for a block diagram of the Radar Data Display System. The MSQ-1A and MOD III radar target range and azimuth information is entered into the Track Radar Evaluator in electrical servo form. The Track Radar Evaluator converts the servo information into BCD information in which the radar range is in yards and the radar azimuth is in counts where 72,000 counts are equivalent to 360°. The Pick-Off Unit, see block diagram, Figure 47, samples and removes the range and azimuth and converts the information to range in nautical miles and azimuth in degrees. This is accomplished by a BCD divider. Dividing the range in yards by 2,000 converts the range to nautical miles to within one mile of accuracy. Dividing azimuth in counts by 200 converts the counts of azimuth to degrees of azimuth to within 1 degree. The divider is straight forward and no problems were encountered in its design. After division, the radar information is stored in a shift register and sequenced out serially to modulate a carrier oscillator. This serial code is then transmitted to control units via the land line.

The carrier oscillator changes frequency from 14.5KC for MSQ-1A information to 12KC for MOD III information.

The Timer, figure 48, generates all timing functions such as the time to sample the Radar Track Evaluator for data, the timing pulses to change the carrier oscillator, etc. The only problem encountered during check-out and installation of the Pick-Off Unit was in the area of timing. Due to insufficient knowledge of the Track Radar Evaluator, the Timer was generating improper timing pulses and, thereby, causing the Pick-Off Unit to extract data other than range and azimuth information from the Track Radar Evaluator. After the improper timing condition was found, it was a simple matter to isolate and remedy the condition.

2.3.2.1 Control Unit

A block diagram of the Control Unit is seen in Figure 49. The serial BCD radar code is received from the land line. The MSQ-1A and MOD-III radar information carrier frequencies are separated by two band-pass filters. The radar data to be displayed is then selected by a relay which is operated by a manually controlled switch (Radar Selector Switch). The radar data is converted from serial BCD to parallel BCD by the shift register. The radar data is then transferred to a storage register where it is stored for a period of one second. Connected to the storage register are Nixie drivers which matrix the BCD code to decimal decade and drive Nixie tubes in the Decimal Readout Unit to indicate visually the radar range and azimuth.

No problems were encountered in the design, fabrication and installation of the Control Units.

2.3.3 AMDPS Modification

A complete theory of operation of the modified AMDPS Data Recorder will not be presented here since this is available in the Instruction Manuals. A brief description of the system operation, including operating difficulties encountered during fabrication, check-out, and installation will be discussed. A Functional Block Diagram referring to the system operation is shown in Figure 50.

Figure 51 shows the paper tape format which is one of the goals of the modifications. The time required for the AMDPS Data Recorder to process and record the information shown in the output tape format of Figure 51 is two seconds. The first step towards establishing the format was to better utilize the available recording time.

60 pps is the basic timing rate of the AMDPS Data Recorder; this is the rate at which the punches operate. Since 60 pps is the maximum paper tape punch speed, it was decided to speed up the data rate so that two parameters of data would be recorded in each Datatron 205 word. Changing the data rate required a 10 pps switching rate of the Parameter Commutator to replace the former switching rate of 5 pps. Utilizing the same circuitry that provided the 5 pps, the time constant of the Monostable Binary Unit #R3 was changed by replacing the timing resistor referred to in Note 1 of Figure 52, so that the 60 pps

was divided down to 20 pps. The 20 pps was then divided down to 10 pps by another Monostable Binary Unit, #R5. A potentiometer, #R6, providing fine adjustment to get 10 pps, did not have sufficient range to provide a stable 10 pps rate in all the modified AMDPS Data Recorders. Replacing the timing resistor of Module #R5, referred to in Note 2 of Figure 52, provided the proper timing, with sufficient adjustment of resistor #R6, for a stable 10 pps rate in all the modified AMDPS Data Recorders.

Since the data rate was doubled, the next step in the modifications was to expand the Parameter Commutator so that twenty parameters could be recorded by the AMDPS Data Recorder. Since it was necessary to record all the data with one punch, there was no need for two seperate commutators; the Operational Parameter Commutator and the Maintenance Parameter Commutator. Wiring changes connected the two commutators together, and eighteen of the twenty Bistable Binary Linear Counter Units, type 111, used in the Parameter Commutator shown in Figure 52 were connected. The uniting of the two commutators eliminated the need for module #Q9, formerly used for switching of the Maintenance Commutator, which was then rewired for use as the nineteenth unit in the Parameter Commutator. Spare module #D8 was then wired for use as a Bistable Binary Linear Counter Unit thus completing the twenty unit Parameter Commutator shown in Figure 52.

Operation of the AMDPS Data Recorder on a Scan basis was achieved by modifying the Parameter Commutator. During Normal operation, the Parameter Commutator is operating as a continuous ring counter. It was necessary to interrupt the continuous ring counter and change the operation so that the Parameter Commutator would operate as a broken ring counter when in the Scan mode. Referring to Figure 52 it can be seen that there are twenty-two Bistable Binary Linear Counter Units which can be connected together in the Parameter Commutator when switch S-502 is in the Scan position. The twenty-first module in the Parameter Commutator, #D7, is used to key the Parameter Commutator off at the end of a cycle by not allowing the Linear Counter Bias to set one of the preceeding twenty units; the twenty-second module in the Parameter Commutator, #D6, is used to start operation when a Scan Mark occurs. The Scan Mark is generated by a relay closure in the Control PPI scope and shaped for a sharp negative leading edge by a Schmitt Trigger, module #X552.

During the operational checkout of the modified AMDPS Data Recorder at Radiation Incorporated, it was discovered that the planned method of connecting the Blip/Scan and Jamming Effectiveness Switchboxes to the AMDPS Data Recorder generated trouble in the Parameter Commutator. Erratic operation of the Parameter Commutator was observed when (1) the 115 volts AC from the AMDPS Data Recorder was used to energize the solenoid release of the switchboxes, and (2) when the +6 volts from the AMDPS Data Recorder was used to energize the recording lamps of the switchboxes. One of the parameter pulses used to energize the lamps in the switchboxes; M-7, M-8, Blip/Scan, or Jamming Effectiveness parameter pulse, or the parameter pulse used to energize the solenoids in the switchboxes, M-9, would sometimes be cut short and a random Bistable B inary Linear Counter Unit in the Parameter Commutator would then set thus destroying the normal mode of operation of the ring counter. The elimination of troubles encountered between the Switchboxes and the Parameter Commutator are discussed with the design of the switchboxes presented later in this section.

Two additional troubles were encountered with the Parameter Commutator after installation and during checkout of the remaining six modified AMDPS Data Recorders at the Verona Site. Both troubles caused erratic operation of the Parameter Commutator; parameter pulses would not be in synchronization with the 10 pps timing rate and some parameter pulses would not be present, resulting in a cycle of operation being less than two seconds. Investigation of this problem revealed that (1) dirty tape punch perforator contacts resulted in an erratic 60 pps reference which accounted for false triggering of the 20 pps and 10 pps Monostable Binary Units and (2) when the Scan-Normal Switch, S502, was in the Scan position, the Linear Counter Bias of the Bistable Binary Linear Counter Units, which was connected outside the RF proof enclosure to switch S502 on the front panel picked up noise from the punch motor on the wiring outside the RF shield.

The dirty perforator contacts were replaced in one modified AMDPS Data Recorder and cleaning of the perforator contacts in another modified AMDPS Data Recorder restored proper operation of the timing circuitry.

The problem of the Scan-Normal Switch, S-502, allowing noise pick-up on the Linear Counter Bias of the Parameter Commutator was the most difficult trouble to isolate. An oscilloscope was used to observe the voltage level of the Linear Counter Bias and no noise could be observed since a Bistable Binary Linear Counter Unit would set at the instant that noise occurred. Capacitors were connected between ground and the Linear Counter Bias with the result of either stopping operation of the ring counter or [illegible] by-passing the noise to ground. It was then decided to use the Scan-Normal switch to energize a relay, mounted on the rear door inside the RF enclosure of the AMDPS Data Recorder and near the Parameter Commutator, to connect the Linear Counter Bias to the twenty-first and twenty-second Bistable Binary Linear Counter Units when operating in the Scan mode, thus eliminating the need for the Linear Counter Bias wiring to be outside the RF Shield and this avoided the noise pick-up from the front part of the recorder.

The Parameter Commutator output pulses are used to gate analog voltages into the Analog to Digital Converter similarly to the previous method used. The previous method used seventeen relays for connecting three operational parameter voltages, thirteen maintenance parameter voltages, and a zero reference voltage through a series connection of the relays to the Analog Voltage Buss to the Analog to Digital Converter. The present method used in the modified AMDPS Data Recorders utilizes a total of sixteen relays which connect fifteen analog parameter voltages; Range, Azimuth, nine maintenance, and the four spare analog inputs designated as AS, SS, S/N, and SP in addition to the zero reference voltage which is connected through the Analog Voltage Buss, to the Analog to Digital Converter during the Blip/Scan parameter pulse. Zeroing the Analog to Digital Converter during a digital parameter, Blip/Scan, provides the means for recording digital data on the output tape during a period when the Analog to Digital Converter cannot supply digitized analog data to the Punch Amplifiers. No operating difficulties at Radiation Incorporated were encountered with this method of reading in the analog voltages to the Analog to Digital Converter through the series connection of relays shown in Figure 52, however, after installation and during checkout of the modified AMDPS Data Recorders at the Verona Site, it was discovered that the relays used to read in the analog voltages would malfunction due to dirty contacts of the relays. The dirty contacts of the relays resulted in bad data for the preceeding analog voltages connected in series through the faulty relay. Operation of the faulty relay was restored to normal by cleaning the contacts or readjusting the spring tension of the contacts, however, it is felt that this trouble will occur often in the future and some suggestions to alleviate the recurrence of bad data due to faulty relay contacts are offered in section 3.3.

Minor wiring changes were performed on the Minor Scan Gate, module #F1, and the Program Control Gate, module #F2, since these changes are explained in detail in the Instruction Manual, and no difficulties were encountered during checkout, operation, or installation, no theory of operation will be presented in this text, Figure 52 shows the wiring logic of module #F1 and #F2.

Zeroing of the Analog to Digital Converter necessitated rewiring of three pins in the Analog to Digital Converter Section, pins 8 and 9 of module #I1, a Monostable Binary Unit, and pin 8 of module #G11, a Bistable Binary Unit. In addition to zeroing of the Analog to Digital Converter during a different time than previously used, it was decided to provide inhibiting of false code outputs so that when an 8 bit of any decade was present, the 4 bit and 2 bit of the same decade would be inhibited. This feature eliminates the possibility of an invalid character on the output paper tape. Figure 53 shows the logic diagram of the Analog to Digital Converter and the operation of inhibiting the false code is explained in detail in Section 2.2 in the Instruction Manual. No troubles occurred in this part of the modification.

The new logic required for recording Time data and the gating of the analog data will not be presented in this text since there were no difficulties or troubles generated by the new logic and a complete theory of operation of this circuitry is available in the Instruction Manual.

Twenty new switchboxes, ten Blip/Scan switchboxes and ten Jamming Effectiveness switchboxes, were fabricated. One modified AMDPS Data Recorder can record data from five Blip/Scan switchboxes and five Jamming Effectiveness switchboxes. The data recorded is determined by the operator when he manually depresses a push-button. Only one button may be depressed at any one time and all other push-buttons are locked out until the significant data is recorded in the AMDPS. A solenoid, mounted on the switches, provides the release function for the push-button switches.

The release solenoid of the switchboxes is rated at 115 volts AC and 500 ma. Initial concept called for the 115 volts AC to be wired from the AMDPS Data Recorder, however, this method proved to be unsatisfactory due to transients occurring inside the AMDPS Data Recorder whenever the solenoid was energized or de-energized. The transients would cause false triggering of the Parameter Commutator, as explained when the Parameter Commutator was discussed. It was evident that control of the switchboxes had to be initiated by the AMDPS Data Recorder. The difficulty was resolved by controlling a relay mounted in the switchbox. The relay, upon a command derived in the Data Recorder, connects 115 VAC to the reset solenoid in the switchboxes. The 115 VAC when connected to the reset solenoid will cause the depressed switch to be reset.

A lamp is mounted on the switchbox to indicate when switchbox data is being recorded at the AMDPS Data Recorder. This visual cue is used by the operator to enter new data into the switchbox. The 6 volts needed to light the lamps was originally obtained from the +6 volts supply in the AMDPS Data Recorder. Connecting more than five switchboxes to one AMDPS Data Recorder proved to be too much of a load on the +6 volt supply in the recorder and resulted in false triggering of the Parameter Commutator. An Auxiliary 6 volt Power Supply, shown in Figure 54 was added to the AMDPS Data Recorder for the purpose of providing 6 volts to light the lamps in the switchboxes. The addition of the Auxiliary Power Supply eliminated the voltage variation of the AMDPS +6 volt power supply to other circuitry in the AMDPS Recorder when the switchbox lamps were energized.

The FPS-6 radar is a height-finding radar with a shorter sweep cycle than any of the other radars under observation. The other radars being monitored are azimuth rotating devices, but the FPS-6 antenna nods up and down rather than rotating in a circular motion. A complete cycle of motion for the FPS-6 radar consists of two nods; one nod is up and the other nod is down. The fastest time of a nod is three-quarters of a second, therefore, a complete cycle of operation is two nods, and the period is 1.5 seconds. It is obvious that 1.5 seconds is too fast for the twenty unit Parameter Commutator to operate with a triggering rate of 10 pps, since a complete cycle of the Parameter Commutator takes 2.0 seconds.

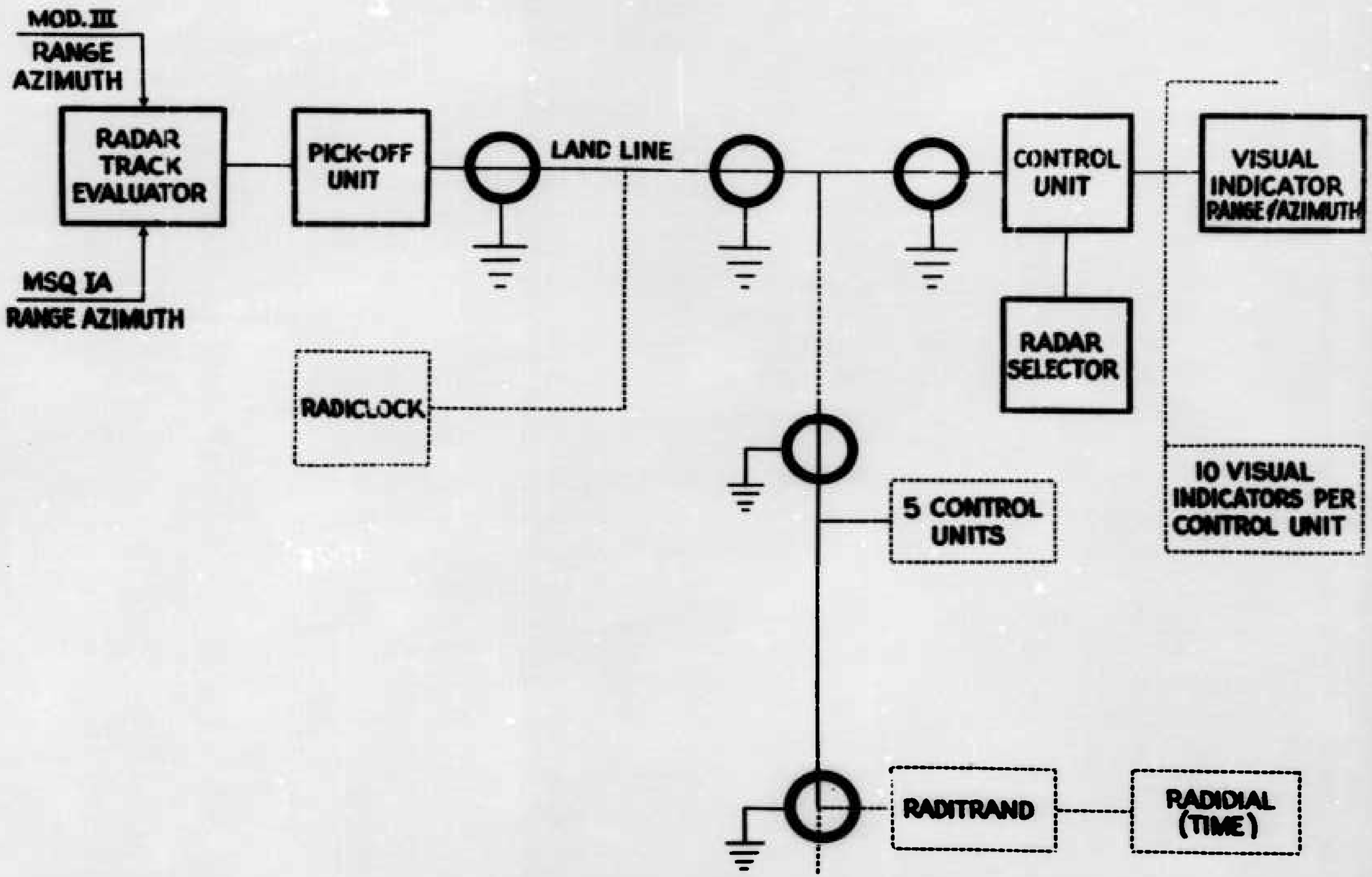


Figure 46. Radar Data Display System - Block Diagram

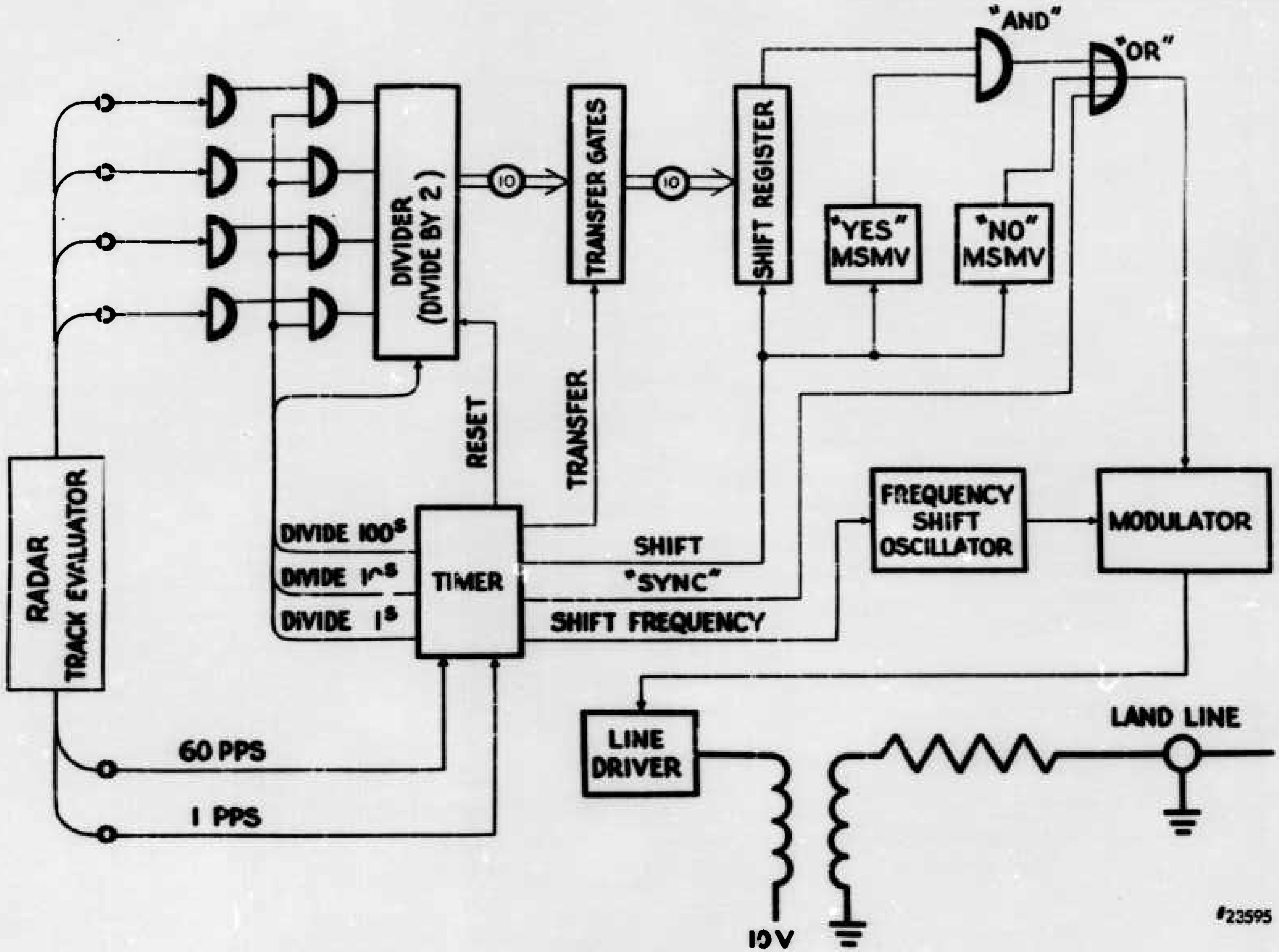
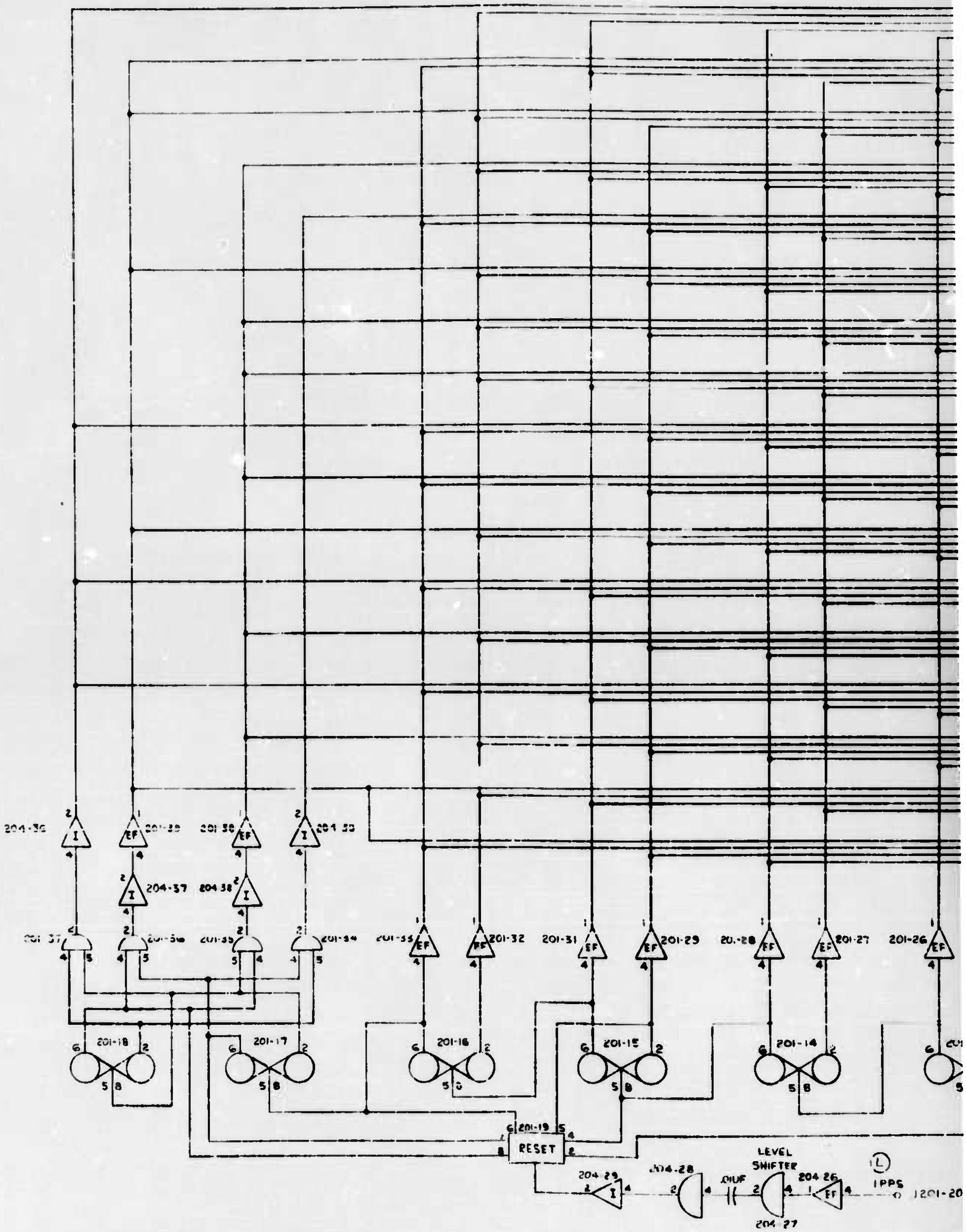
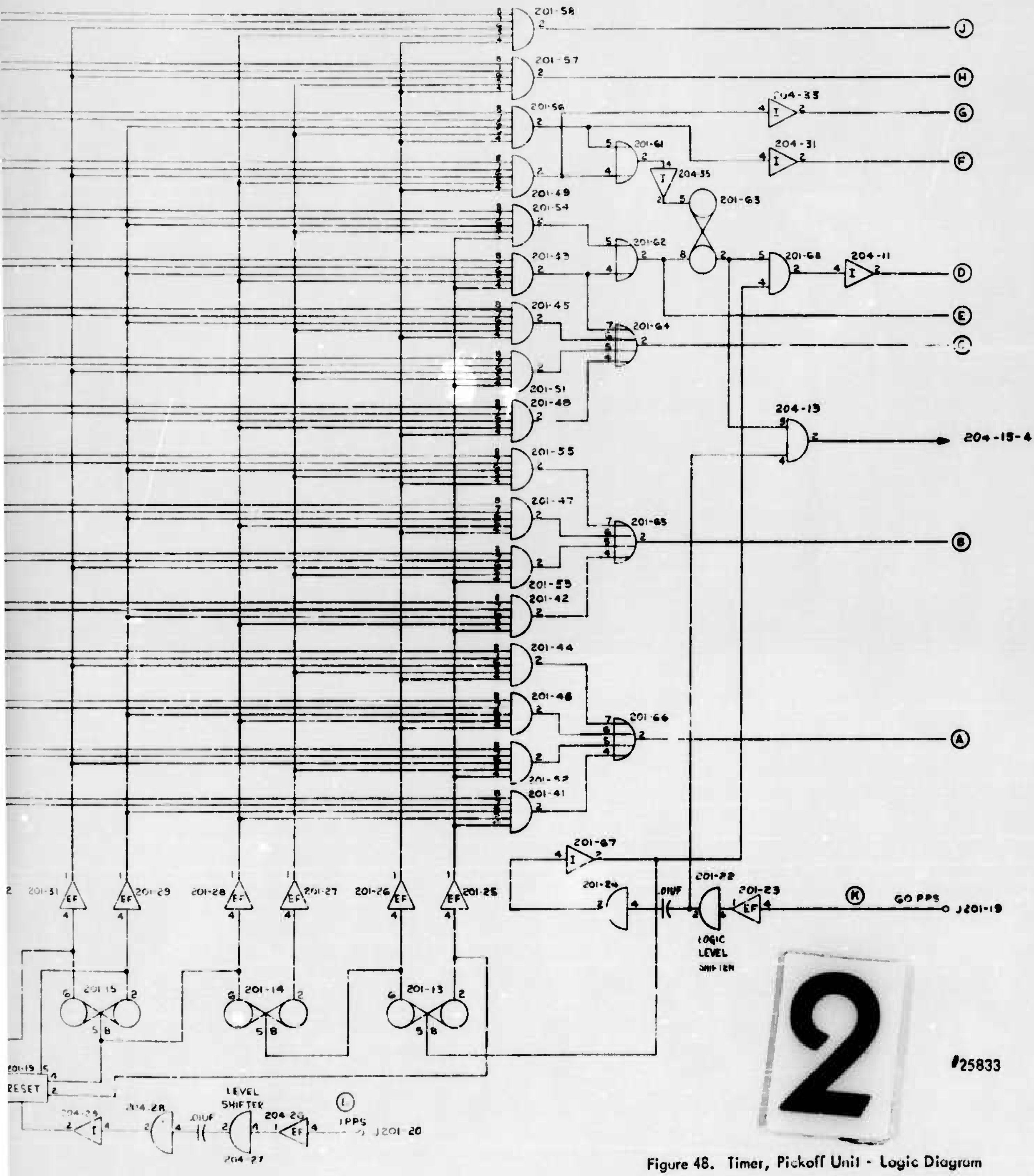


Figure 47. Pickoff Unit - Block Diagram



201-18
201-17
201-16
201-15
201-14
201-32
201-29
201-27
201-26
201-31
204-37
201-19
RESET
LEVEL
SHIFTER
204-29
204-28
204 27
.01UF
1PPS

1



2

#25833

Figure 48. Timer, Pickoff Unit - Logic Diagram

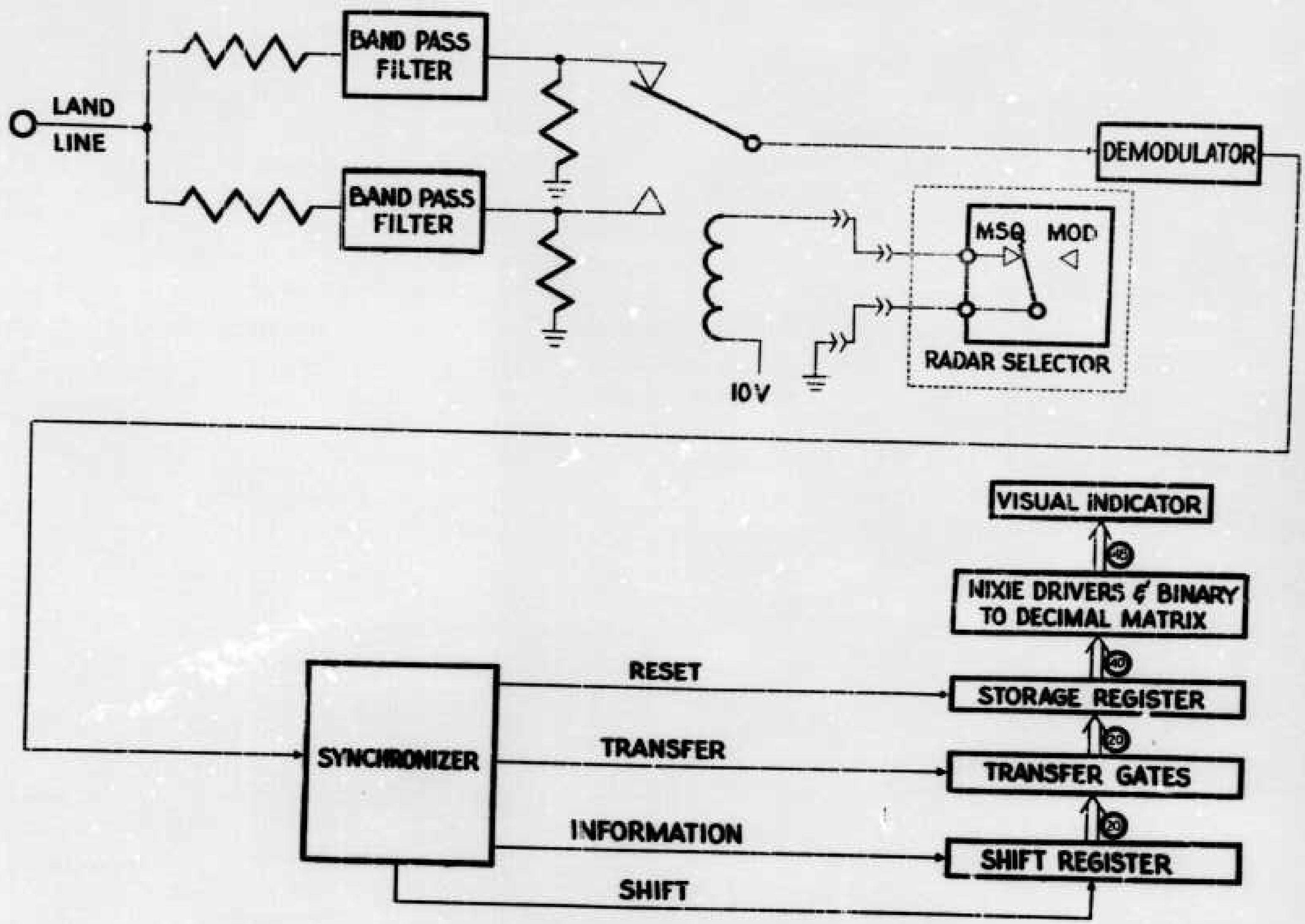


Figure 49. Control Unit – Block Diagram

#23592

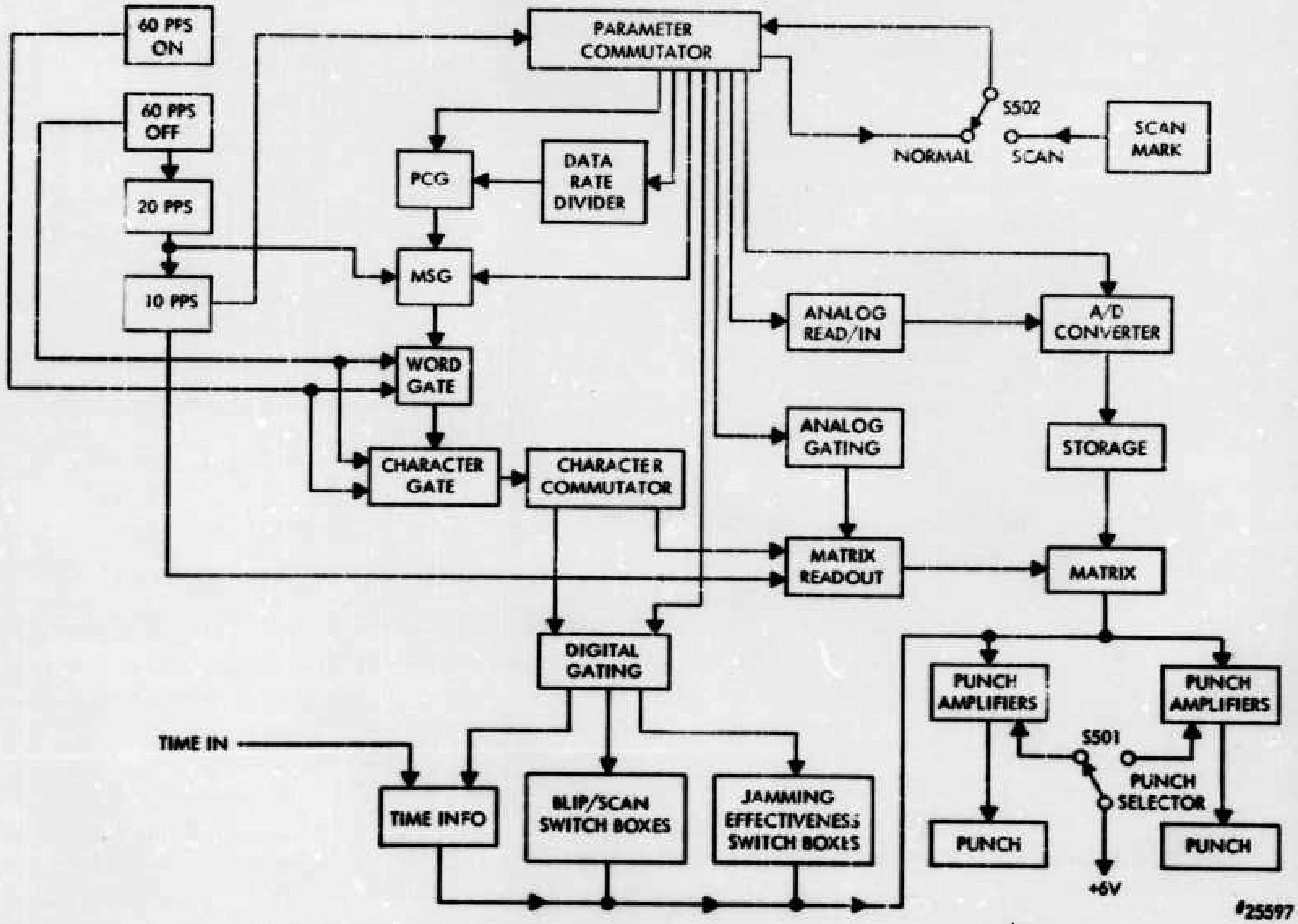


Figure 50. AMDPS Data Recorder – Functional Block Diagram (MOD)

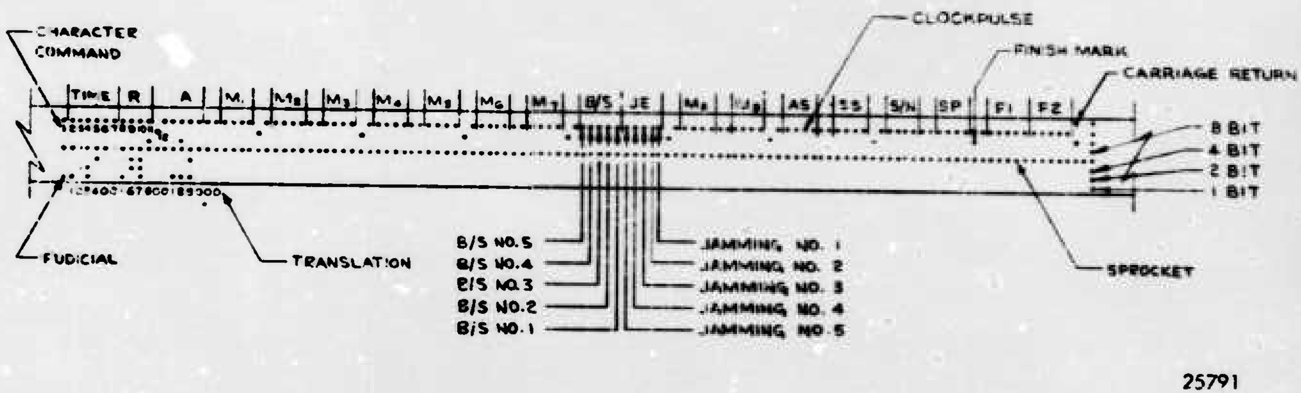
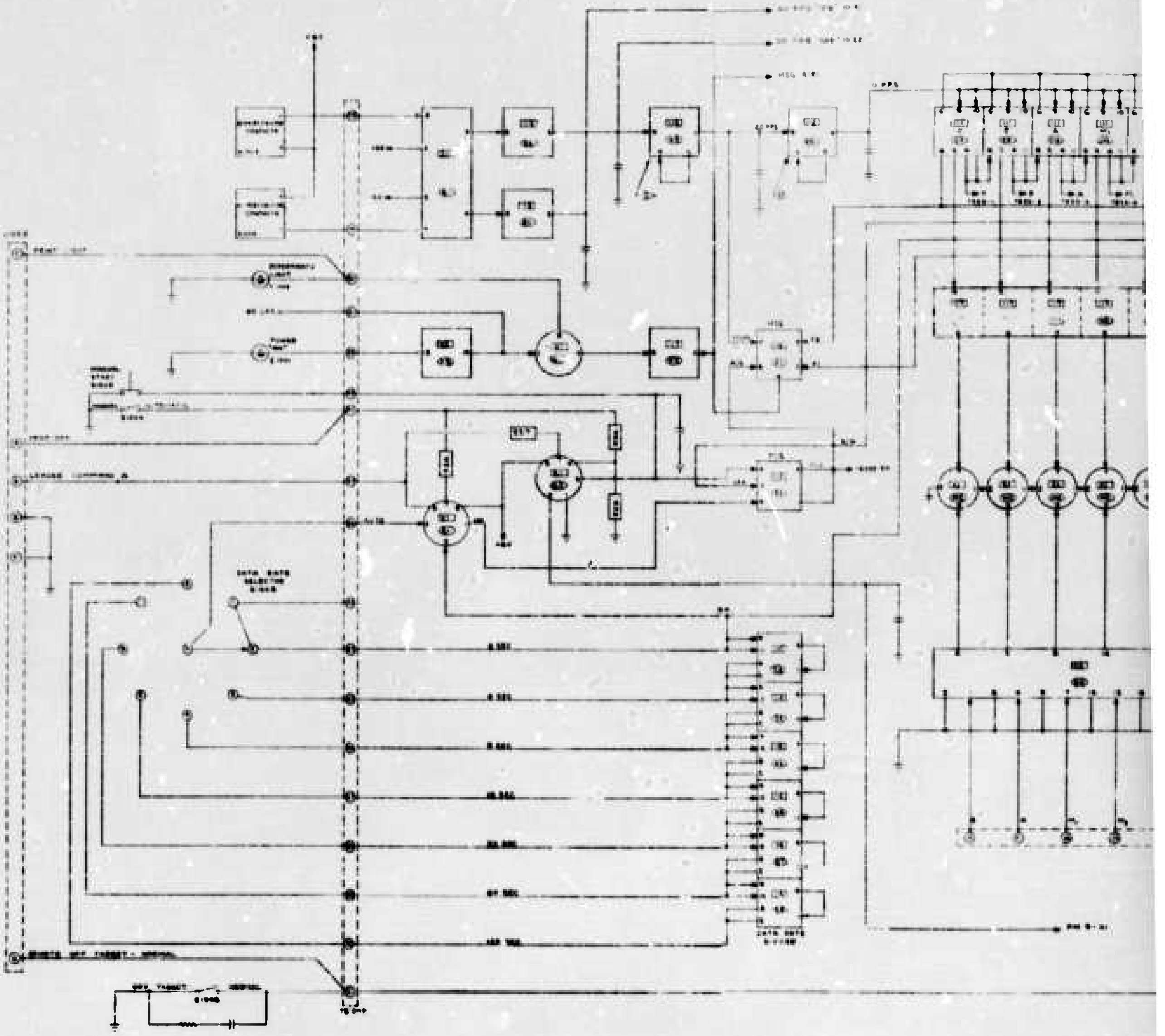


Figure 51. Paper Tape Output Format (MOD)



1

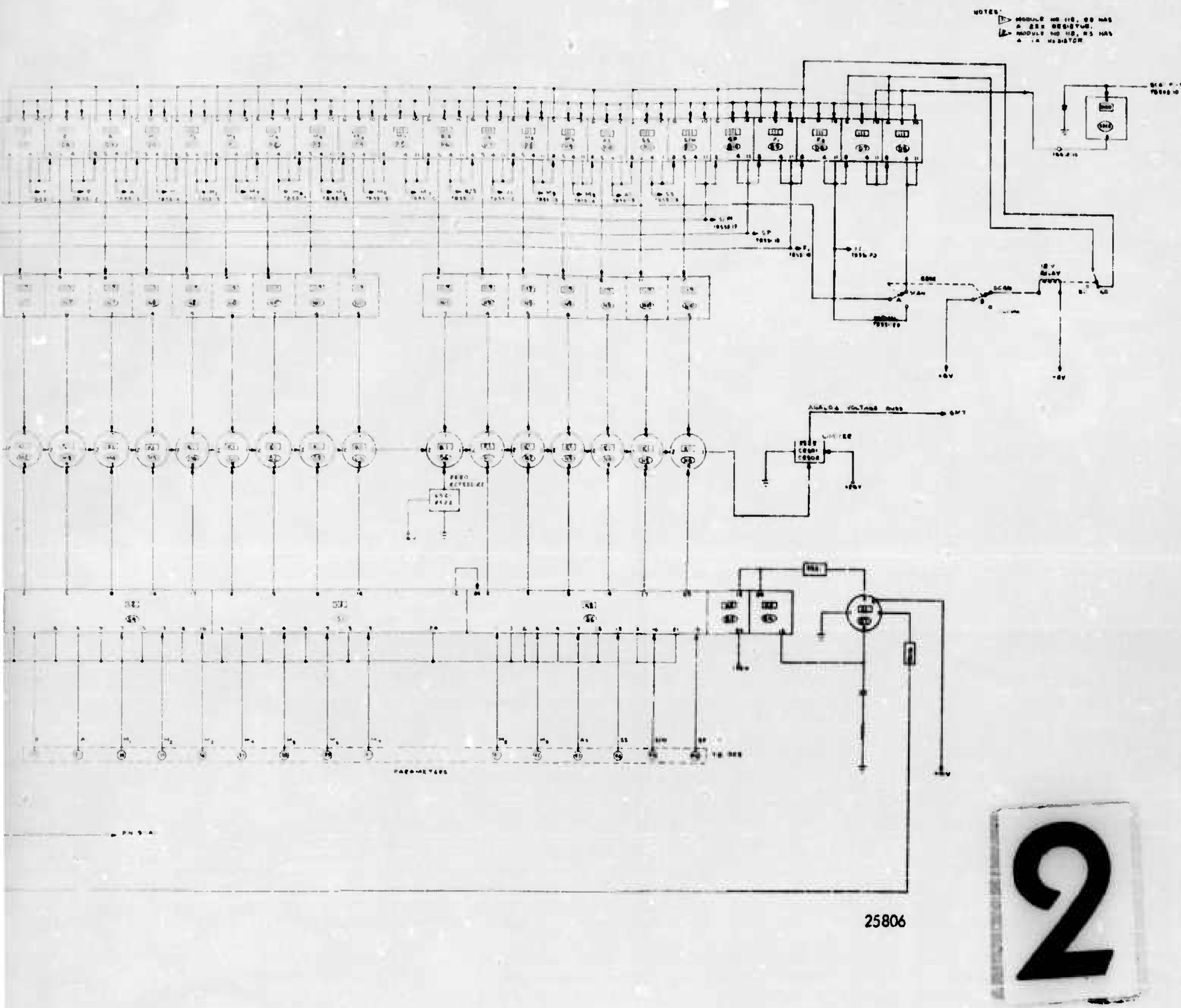


Figure 52. Parameter Commutator - Logic Diagram (MOD)

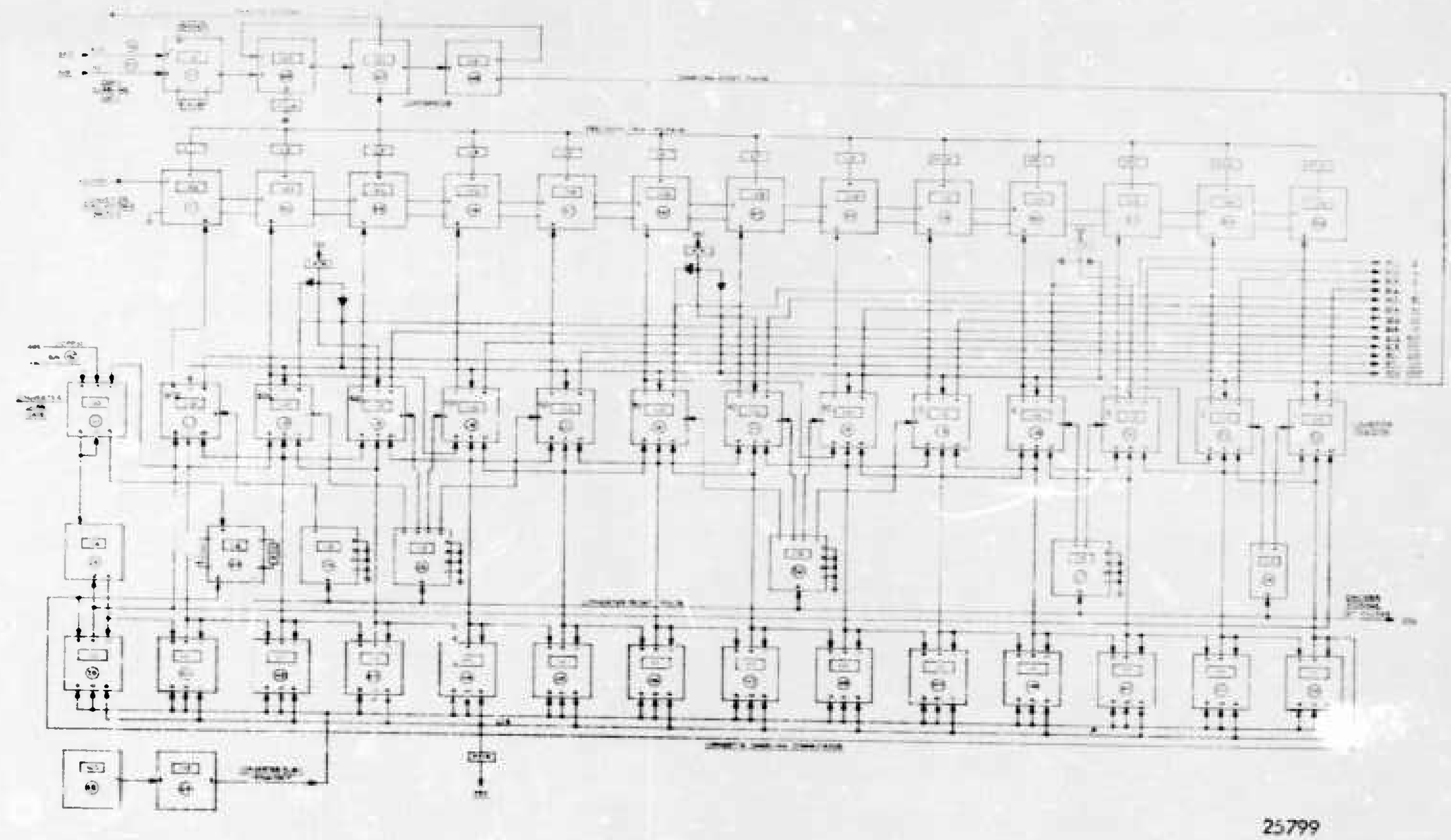
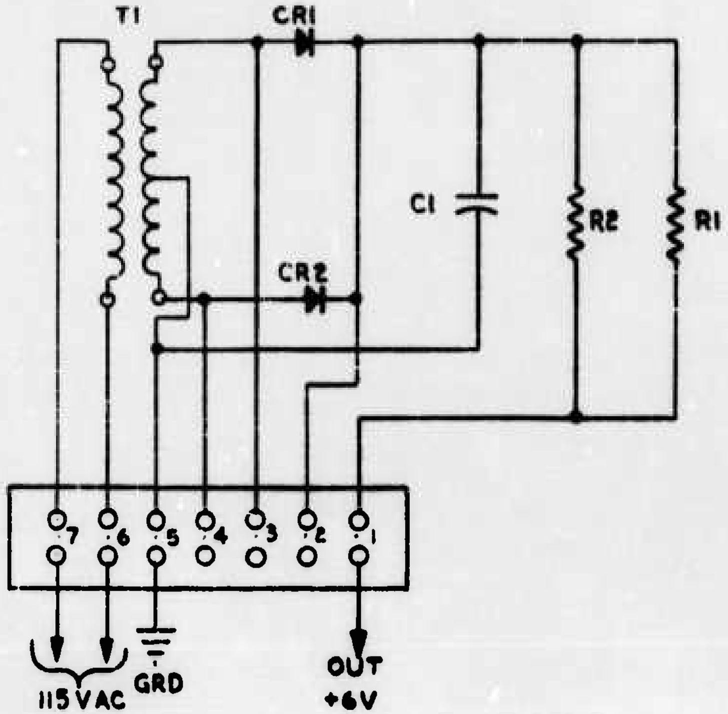


Figure 53. Analog to Digital Converter - Logic Diagram (MOD)



NOTES:

1. T1 - TRANSFORMER - TRIAD F-25X
2. CR1 & CR2 - DIODE, MOTOROLA IN536
3. C1 - CAPACITOR - AEROVOX, AFH 1-10
   1000 UF, 25 VDC
4. R1 & R2 - RESISTOR - 15 Ω, 1/2 W, ±5%
5. TERMINAL STRIP - CINCH - JONES 7-140
6. R1 & R2 RESISTORS ARE REMOVED FROM POWER SUPPLIES IN AMDPS FOR FPS-6, FPS-20, NIKE & FPS-15.

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Figure 54. Auxiliary Power Supply - Schematic Diagram (MOD)

Remove Following Modules:

X550	N4	P11
X554	N5	Q9
D8	N6	Q10
N3	P10	Q11

Wire Jumpers As Listed:

FROM		TO	
PIN	MODULE	PIN	MODULE
11	D8	11	P9
1	N2	1	N6
11	P4	11	Q11
11	P5	11	Q10
11	P8	11	Q9

#25785

Figure 55. FPS-6 Modification - AMDPS

Slight modifications to the modified AMDPS Recorder in Building #4 associated with the FPS-6 radar provided compatibility between the FPS-6 radar and AMDPS recorder. The twenty unit Parameter Commutator was shortened so that only fourteen Bistable Binary Linear Counter Units, type 111, were used. The FPS-6 radar parameters to be recorded are Time, Range, M-1, M-2, M-3, M-4, M-5, M-6, M-7, Blip/Scan, Jamming Effectiveness, M-8, and M-9. Thus, the four spare analog parameters; AS, SS, S/N, and SP, and the two spare digital parameters, F-1 and F-2 will not be recorded in the AMDPS used with the FPS-6 radar. The total time for one AMDPS cycle will be 1.4 seconds for the fourteen parameters.

The output tape format will appear as shown in Figure 51 with the exception that the carriage return will apear at the end of the M-9 parameter and the following six parameters will be missing from the tape, namely; AS, SS, S/N, SP, F-1 and F-2. A list of changes needed to accomplish the alteration of the AMDPS to the FPS-6 radar is shown in Figure 55. The Scan recording feature is still available with a Scan mark being generated only on the down nod of the FPS-6 radar. No installation or operating difficulties were encountered during and after this modification to the FPS-6 radar.

3.0 RELIABILITY

3.1 Summary

Reliability has been considered on an equal basis with performance and cost throughout the development of the RADC Data Gathering Instrumentation System. The present system configuration represents a near optimum combination of these influencing factors. The reliability program was divided into the four (4) major areas, listed below:

(a) Planning
(b) Design Criteria
(c) Analysis
(d) Testing

Proper implementation and control in these areas has provided a high degree of reliability assurance in the end product.

Manifestation of the work accomplished in these areas is available in the documents listed below. Proper control of these areas is readily discernible in any attempt to evaluate system performance.

Reliability Plan
General Derating Philsosphy
Reliability Prediction Reports
Test Procedures and Reports

Radiation Incorporated has a high degree of confidence that the equipment designed, manufactured and delivered on this contract will continue to demonstrate reliability characteristics which will exceed those required and which will be equal to or better than those predicted.

3.2 Reliability Prediction

A summary of reliability calculations is presented in Table II. This table provides direct comparisons between the required, predicted and test reliabilities. The required reliability values were calculated in accordance with Paragraph 3.2 of Exhibit RADC-2629, dated 31 October 1958, since specific values were not specified elsewhere. The reliability values shown are based on an assumed mission operating time of eight (8) hours. It should be noted that the AMDPS modification is not considered or reflected in calculations or discussions presented herein. The required and predicted reliability and Mean-Time-Between-Failure (MTBF) values (shown in the first four columns of Table II)were calculated in the following reports:

(1) Radiation Incorporated Preliminary Reliability Prediction for the Ground System, dated 20 May 1960.

(2) Radiation Incorporated Preliminary Reliability Prediction for the Airborne System

The column entitled "Probability of Mission Success" indicates the statistical probability, derived from the predicted MTBF values, of completing an eight hour mission with no (zero) failures.

TABLE II

SUMMARY OF RELIABILITY CALCULATIONS

SYSTEM	REQUIRED REL.	REQUIRED MTBF HOURS	PREDICTED REL	PREDICTED MTBF HOURS	PROBABILITY OF MISSION SUCCESS	TEST INDICATIONS	OPERATOR INFLUENCE	MAINTENANCE INFLUENCE
Radar Display	0.91312	83	0.97859	255	97%	Reliability is better than predicted	None	None
A/B Time Decoder	0.98328	479	0.99283	1115	99%	Reliability is better than predicted	None	None

The column entitled "Test Indications" is indicative of the test results summarized in Paragraph 3.3. The columns entitled "Operator Influence" and "Maintenance Influence" are explained in Paragraph 3.4.

3.2.1 Prediction Details Radar Display System

The predicted MTBF for the Radar Display System is 255 hours as shown in Table II. This value is slightly greater than three (3) times the calculated required value of 83 hours. The prediction was based on a maximum operating temperature of 30°C and component deratings of 10% for logic circuits and 50% for power supplies. The results of the tests (see Paragraph 3.3) indicate the predicted MTBF is valid, if not slightly conservative, since the maximum test temperature was 50°C and Life testing indicates a lower NOR module failure rate than was predicted.

3.2.2 Prediction Details Airborne Time Decoder

The predicted MTBF for the Airborne Time Decoder is 1115 hours as shown in Table II. This value is more than two (2) times the calculated required value of 479 hours. The prediction was based on a maximum operating temperature of 50°C and component derating of 50% for all circuits. Test results (Paragraph 3.3) tend to confirm this prediction. However, the prediction may prove to be conservative for the following reasons:

(a) Life test results indicate a longer NOR module life than was predicted.

(b) Some components, particularly in logic circuits, are known to operate at lower derating levels than those used in the prediction

(c) The maximum operating temperature used for prediction purposes was 50°C. This temperature is probably higher than the average flight operating temperature which will be encountered.

3.3 Summarized Test Results

3.3.1 NOR Module Life Test

The NOR module was selected for life testing and it was used as the basic system building block for both the Radar Display System and the Airborne Time Decoder. Basic factors leading to this choice are:

(a) NOR modules comprise over 60% of the Airborne Time Decoder circuitry.

(b) NOR modules constitute about 80% of Radar Display System circuitry.

(c) NOR modules are similar to bistable multivibrator modules with respect to electrical and physical characteristics. The life test results would provide a good indication of bistable life characteristics. Bistables constitute an additional 15 to 20% of each system.

The Life Test was conducted using 500 NOR modules. The total test time was 3383.9 hours for each module. This represents a total cumulative test time of 1,691,950 hours for the 500 modules. During this test time, one failure occurred at 2760.9 hours. Thus, a cumulative failure free test time of 1,380,450 hours was accrued. This would tend to indicate that the MTBF prediction, also based on 30°C, of 413,223 hours is conservative. This is one reason why the "Reliability is better than predicted" is entered in Table II in the "Test Indications" column.

3.3.2 Systems Environmental Testing

3.3.2.1 Radar Display System

The Radar Display System was subjected to an operating temperature test. During this test, the system was exposed to temperatures ranging from -10 to -50°C. It is significant to note that no (zero) failures were observed, while the temperatures indicated are more severe than those likely to be encountered under actual system service conditions. This accounts for the "Reliability is better than predicted" entry in Table II.

3.3.2.2 Airborne Time Decoder

The Airborne Time Decoder was subjected to temperature, shock and vibration tests. No (zero) failures were observed during any of these test. Thus, the appropriate entry was made in the "Test Indications" column of Table II.

3.4 Other Reliability Considerations

3.4.1 System Weakness Identification

The two systems do not have any known weak areas or features. However, the more severe environment imposed on the Airborne Time Decoder would indicate a faster system deterioration rate compared to that of the Radar Dispaly System. No real evidence in support of this theory is available at this time.

3.4.2 Reliability Improvement Measures

Radio Frequency Interference (RFI), radiated by juxtapositioned equipments, was conducted by the Radar Display System and the Airborne Time Decoder. Conducted RFI resulted in erratic system performance. This situation was remedied by the installation of RFI shielding where necessary.

No other problem areas have been indicated.

3.4.3 Operator Influence

The Radar Display System can be operated by a single power switching operation. No decrease in system reliability as a result of variations in operator skill is anticipated for this system.

The Airborne Time Decoder requires the operator to perform five (5) basic functions:

(a) Power ON-OFF

(b) Time Set

(c) Time Reset

(d) Input Level Adjustment

(e) Output Level Adjustment

Since none of these requirements are complex, an operator with minimum skill could operate the system properly. No system reliability degradation is expected, due to operator skill variations.

3.4.4 Maintenance Influence

The maintainability and human engineering aspects of these systems have been well considered. These features are described in Paragraph 4.0 of this report. No system reliability degradation is expected for either system as a result of reasonable variations in maintenance personnel skill.

4.0 MAINTAINABILITY

One of the prime considerations of this program was the production of equipment which is inherently reliable. By maintaining a low-failure rate, maintenance manhours are kept to a minimum. Since reliability becomes more difficult to achieve as system complexity increase, a concomitant design responsibility is that of maintainability. This may be defined as a quality of the combined features of material, design, and installation which facilitates the performance of maintenance by personnel of average skill under the intended operational environment.

At Radiation Incorporated all concerned, from the system designer to the component engineers, are aware of the influence of design consideration leading to a maintainable unit or system. Some of the prime considerations are included in the following paragraphs.

The accessibility of an item will bear a direct relation to its known failure rate. Items which have a short mean time to failure are easily removable form the major assembly. Items with a long run time to failure do not have to be removed to facilitate replacement of a short-life item. This is not intended to imply that long-lift items are located in hard-to-get areas; accessibility of all items, regardless of their estimated life, are provided.

The majority of the circuit modules are mounted on swingout aluminum boards which makes for ease in removing the module. It also makes accessible the power and signal connection to the modules for troubleshooting the equipment.

Special tools are not required when removing an item from a major assembly. Standard screws, bolts, nuts, clamps, and other mounting hardware are employed.

Units and modules do not require special adjustment or refitting when inserted into a major assembly.

Safety precautions have been observed to assure that personnel are not exposed to physical or electrical hazard when performing repair functions, or to physical strain due to excessively heavy or awkard units.

From the human engineering point of view, there are several techniques which were employed to make the maintenance technician's job more feasible. Some of these include:

(a) Layout — Efficient equipment layout so that electrically - associated items are adjacent to each other, when possible.

(b) Standardization — Standardization of circuits components to the greatest extent practical.

(c) Consistency — Consistency in color coding of wires, control movements, and circuit modules.

The single-circuit module construction improves the downtime due to maintenance. It is a simple matter to troubleshoot digital-type equipment by using a logic diagram showing information flow and module and pin locations. Because digital logic has only two levels, on or off, a maintenance technician with an understanding of the function of the equipment can easily isolate and locate the faulty or malfunctioning circuit module or modules.

The Airborne System and Radar Data Display System use the same circuit modules and have the mechanical layout and design mentioned above.

It will not be attempted to discuss the maintainability of the modifications to the AMDPS. This is because the changes were primarily in wiring. A few circuit modules were added. However, these modules were electrically identical to the existing modules used in the AMDPS. It should be mentioned that all added connectors terminal boards and new module locations were marked to aid in the operation and maintenance of the AMDPS Data Recorder.

5.0 CONCLUSIONS AND RECOMMENDATIONS

Provisions for extended capabilities present in the Airborne System and the Radar Data Display System are outlined per section. Recommendations for further improvement of the AMDPS follows:

5.1 Airborne System

A summary, with recommendations for further expansion of the Airborne System will be discussed in this section.

A minimum of difficulties were experienced in the design, fabrication, checkout and installation of the Airborne System. As previously stated, the Airborne System is an extension of the Time Signal Set AN/USQ-23(V). The purpose of the system is the transmission of a range time code to remote places, namely, Aircraft in flight. The Airborne Time Decoder is used to decode and store the time code. The output of the Airborne Time Decoder will supply the necessary power and signals to control a visual display device, an Airborne Radidial.

In addition to contractual requirements, several additional outputs from the Airborne Time Decoder were furnished for future use. The Airborne Time Decoder has parallel BCD time as a seperate output. This output may be used to drive oscillographic recorders or magnetic tupe recorders.

The Airborne System may easily be expanded by the addition of as many receivers and Airborne Time Decoders as needed. A further expansion of the Airborne System could be the addition of more Radidials per Airborne Time Decoders. At present, each Airborne Time Decoder supplies only one Airborne Radidial. The Airborne Time Decoder can supply signal and power for up to ten Airborne Radidials.

The Airborne System extended the range of the AN/USQ-23(V) Time Signal Set from 2 miles up to 300 miles. The serial BCD Time Code, see Figure 40, is available now in Aircraft participating in the activities and tests taking place at the Verona Test Annex. It should be mentioned again that the Airborne Time Decoder can also be used as an independent Time Code Generator in the event the radio link is blanked out or the Aircraft receiver is out of radio range of the ground based transmitter.

5.2 Radar Data Display System

This section will contain a brief summary of the Radar Data Display System. Recommendations for improvements and future expansion will be presented.

As previously explained, the Radar Data Display System is used to transmit over a land line and display visually at remote sites range and azimuth information from the MSQ-1A and MOD-III radars. The range and azimuth information from both radars is available at the Track Radar Evaluator Unit. The information is available in BCD form. The Pick-Off Unit is used to select the proper information from the Track Radar Evaluator Unit, and after the information is arranged in the proper format, the radar range and azimuth information is transmitted to six Control Units. The outputs of the Control Units are used to control 14 Decimal Readout Units. The layout location of the equipment is seen in Figures 56 through 65.

At this point, it should be pointed out that the Control Unit can select only one set of radar information. The operator has the option of selecting MOD-III radar or MSQ-1A radar information. To display information simultaneously at one site from both radars, two Control Units are required, one for MSA-1A radar information and one for MOD-III radar information.

The system requires the operation of one or both of the radars, and the system requires the operation of the Track Radar Evaluator. It is impossible to eliminate the use of the radars, but the Track Radar Evaluator could be eliminated from system. It would require a seperate servo system and code wheels for each radar to determine the range and azimuth. The system was initially designed to have a seperate servo system and code wheels, but the duplication of equipment proved to be costly, and the code output of the Track Radar Evaluator was used to eliminate the duplication. The Track Radar Evaluator was modified so that the full operating capability of Track Radar Evaluator was not required when the Radar Data Display System is to be operated.

The Radar Data Display system can be expanded with the additions of Control Units along the transmission line. Up to six more Control Units could be added to the present system. The Radar Display system is very similar to the Time Signal Set AN/USQ-23(V) in operation, and, therefore, most of the problems were anticipated. This resulted in a minimum of difficulties in all stages of work.

5.3 AMDPS Modification

A summary of the modified AMDPS Data Recorder capabilities with suggestions for further improving the Data Recorders is presented in this section.

Fifteen analog voltages, from the Automatic Radar Monitoring Systems, Models R-065-2A-1, R-065-3A-1, R-065-4A-1, R-065-5A-1, and R-065-6A-1; and five digital groups of information, namely (1) Time information from the AN/USQ-23(V) Time System, (2) Blip/Scan switchbox information from five Blip/Scan switchboxes, (3) Jamming Effectiveness switchbox information from five Jamming Effectiveness switchboxes, (4) and (5) two spare digital groups designated as F-1 and F-2 can now be recorded on the output paper tape of six of the modified AMDPS Data Recorders. These six modified AMDPS Data Recorders can also be controlled by a Scan Mark from a control PPI which will operate the recorders on a per scan basis with a recording cycle of two seconds. The seventh modified AMDPS Data Recorder, used with the FPS-6 radar, can record nine analog voltages from the Radar Monitoring Systems and three digital groups of data, including (1) Time information from the AN/USQ-23(V) Time Signal Set, (2) Blip/Scan switchbox information from five Blip/Scan switchboxes, and (3) Jamming Effectiveness switchbox information from five Jamming Effectiveness switchboxes in addition to the capability of being controlled by a Scan Mark from a Control PPI scope which will operate the recorder on a per scan basis with a recording cycle of 1.4 seconds.

Four of the seven modified AMDPS Data Recorders also have the added capabilities of recording data from switchboxes located in Headquarters building and these recorders can record on a scan basis with the Scan Mark originating from a control PPI scope in Headquarters building.

Difficulties encountered during the installation and the operating checkout of the modified AMDPS Data Recorders were discussed in Section 2.3. The solutions to the troubles that appeared were given and the results obtained from these solutions were satisfactory, however, two troubles that occurred were only temporarily corrected. Recurrence of trouble is expected from the dirty perforator contacts of the punch motor and the dirty contacts of the relays used to read the analog voltages into the Analog to Digital Converter.

A possible solution to the poor 60 pps reference obtained from the dirty perforator contacts would be to replace this reference by a reference generator. The reference generator would be free of dirty contact trouble and the output from this reference generator could be used for the 60 pps reference.

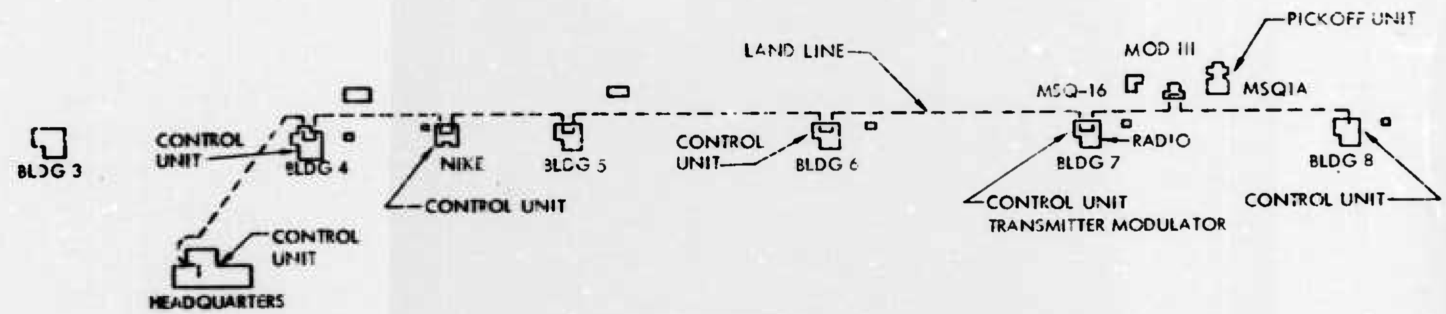
The trouble encountered with the dirty contacts of the relays used for reading in the analog voltages to the Analog to Digital Converter leads to two solutions, both solutions would seem to minimize this trouble and should be used together. The first solution would be to alter the method of connecting the relays in series, and connect the relays in parallel with the wiper arms of the relays being connected together to the Analog Voltage Buss. This method would render a bad data condition to only the analog voltage being read-in by the faulty relay and all other analog data would be unaffected. Figure 66 shows how this method could be wired into the AMDPS Data Recorder.

The other solution to the relay contact problem would be to use more reliable relays. Hermetically sealed relays can be obtained which can operate for tens of millions of operations due to the elimination of contact contamination and the initial cost of these relays could probably be justified by the increase of reliability and the decrease in maintenance time required on the AMDPS Data Recorders.

The modified AMDPS Data Recorders are now operating at the maximum data rate possible with the use of the paper perforator punches. Future considerations towards faster data rates could be obtained with Magnetic Tape Recorders. Magnetic Tape Recorders would also provide more data per tape length, quieter operation, and eliminate the troubles produced by mechanical punches.

Flexibility to the AMDPS Data Recorders could be obtained by the addition of an alarm system which would monitor the output tape and indicate when one of the parameter exceeded pre-set limits. This alarm system could then indicate malfunctions occurring during a test which could be corrected during the test or else cancel the test at the operators option.

An analog monitoring system might also prove useful in plotting channels of analog data for observation, thereby, providing results of interesting data prior to computer analysis.



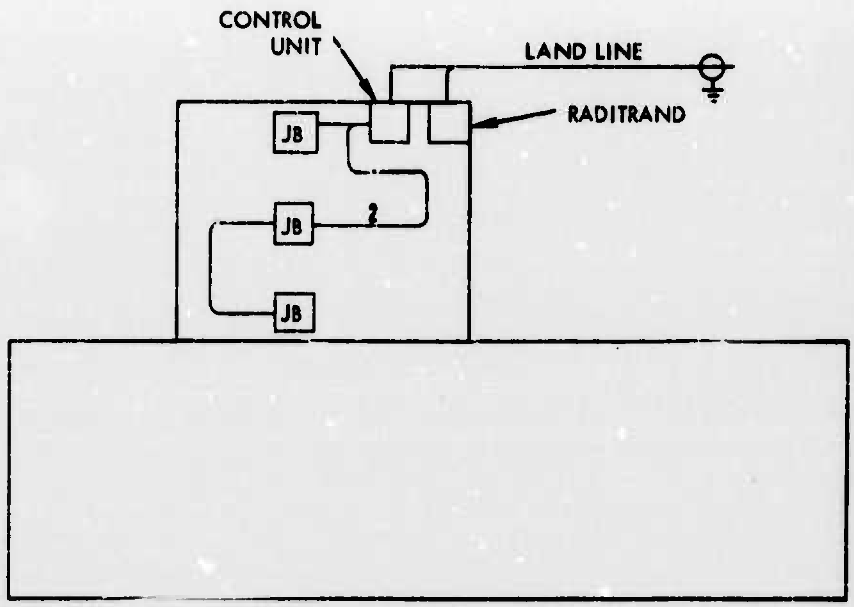
SCALE: 1" EQUALS 400'

NOTE: THE DECIMAL READOUT UNITS ARE DISTRIBUTED AMONG THOSE BUILDINGS HAVING CONTROL UNITS.

NOTE: THE CONTROL UNIT AT BUILDING 7 DRIVES DECIMAL READOUT UNITS AT MSQ-16 MOD III, AND MSQ-1A.

#25769

Figure 56. Verona Radar Data Display System



NOTE:
J.B.-JUNCTION BOXES WITH 12 SEPARATE DECIMAL READOUT UNIT OUTLETS.

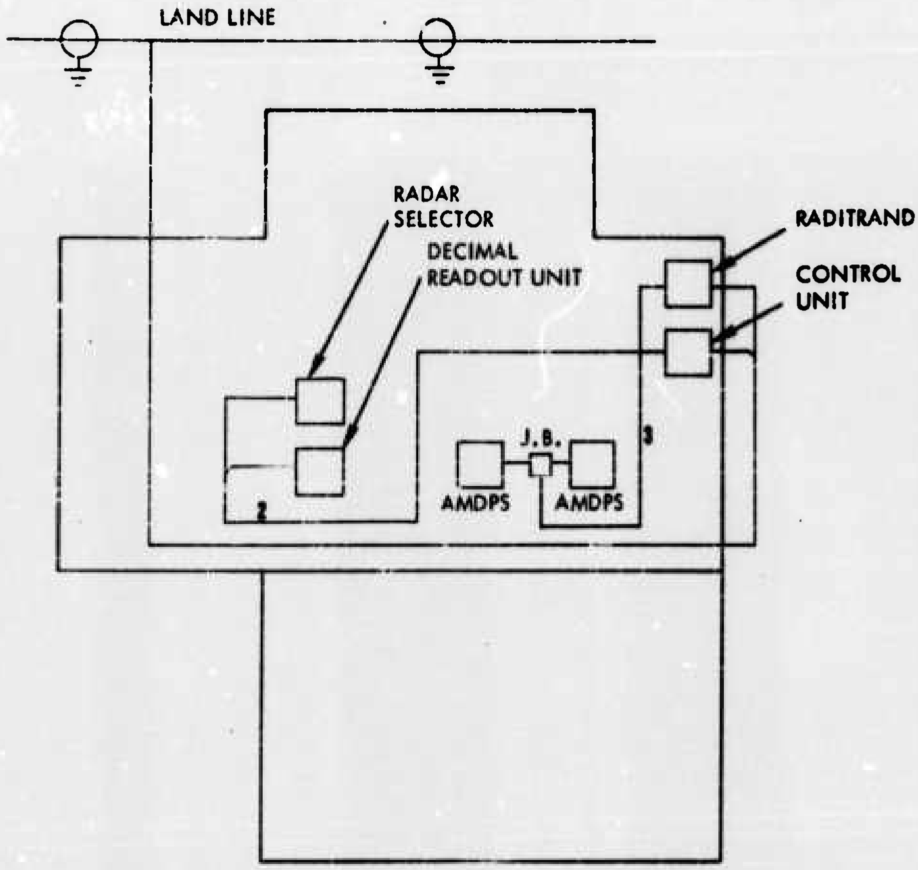
KEY:

1. RADIDIAL
2. DECIMAL READOUT UNIT
3. AMDPS
4. RADAR TRACK PLOTTER
5. OSCILLOGRAPHIC RECORDER

DECIMAL TIME
DECIMAL RANGE AND AZIMUTH
PARALLEL BCD TIME
SERIAL TIME MARKS
SERIAL BCD TIME

#25781

Figure 57. Headquarters Building

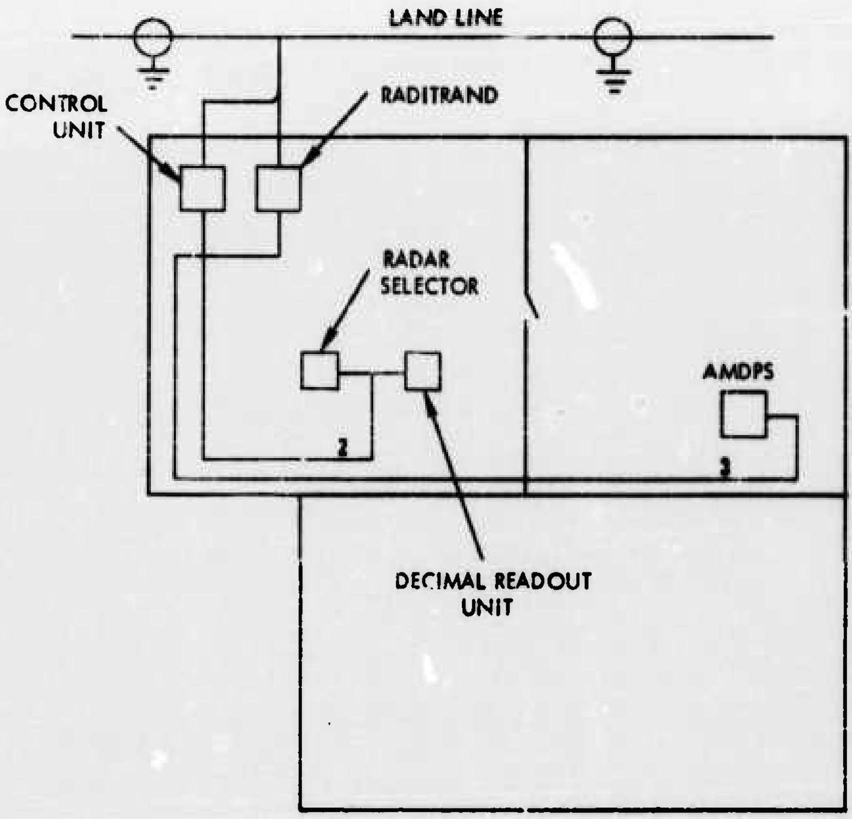


KEY:

1. RADIDIAL	DECIMAL TIME
2. DECIMAL READOUT UNIT	DECIMAL RANGE AND AZIMUTH
3. AMDPS	PARALLEL BCD TIME
4. RADAR TRACK PLOTTER	SERIAL TIME MARKS
5. OSCILLOGRAPHIC RECORDER	SERIAL BCD TIME

#25775

Figure 38. Building #4

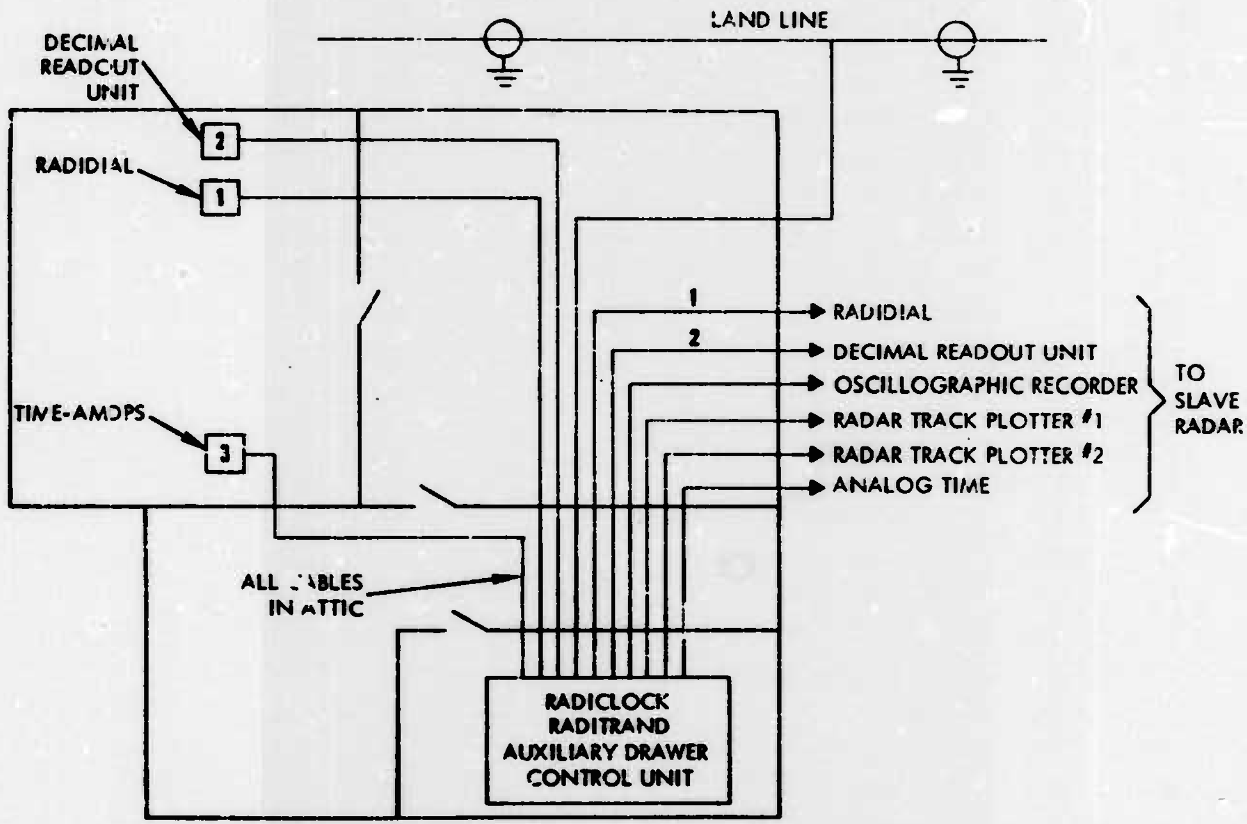


KEY:

1. RADIDIAL	DECIMAL TIME
2. DECIMAL READOUT UNIT	DECIMAL RANGE AND AZIMUTH
3. AMDPS	PARALLEL BCD TIME
4. RADAR TRACK PLOTTER	SERIAL TIME MARKS
5. OSCILLOGRAPHIC RECORDER	SERIAL BCD TIME

#25776

Figure 59. Building #6

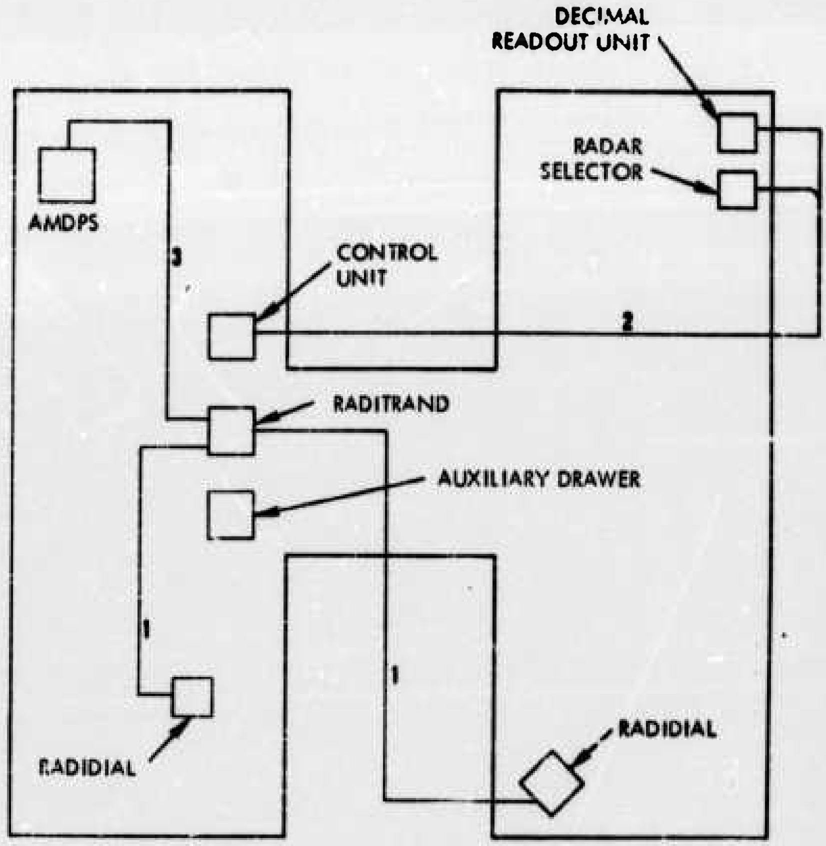


KEY:

1. RADIDIAL	DECIMAL TIME
2. DECIMAL READOUT UNIT	DECIMAL RANGE AND AZIMUTH
3. AMDPS	PARALLEL BCD TIME
4. RADAR TRACK PLOTTER	SERIAL TIME MARKS
5. OSCILLOGRAPHIC RECORDER	SERIAL BCD TIME

#25778

Figure 60. Building #7

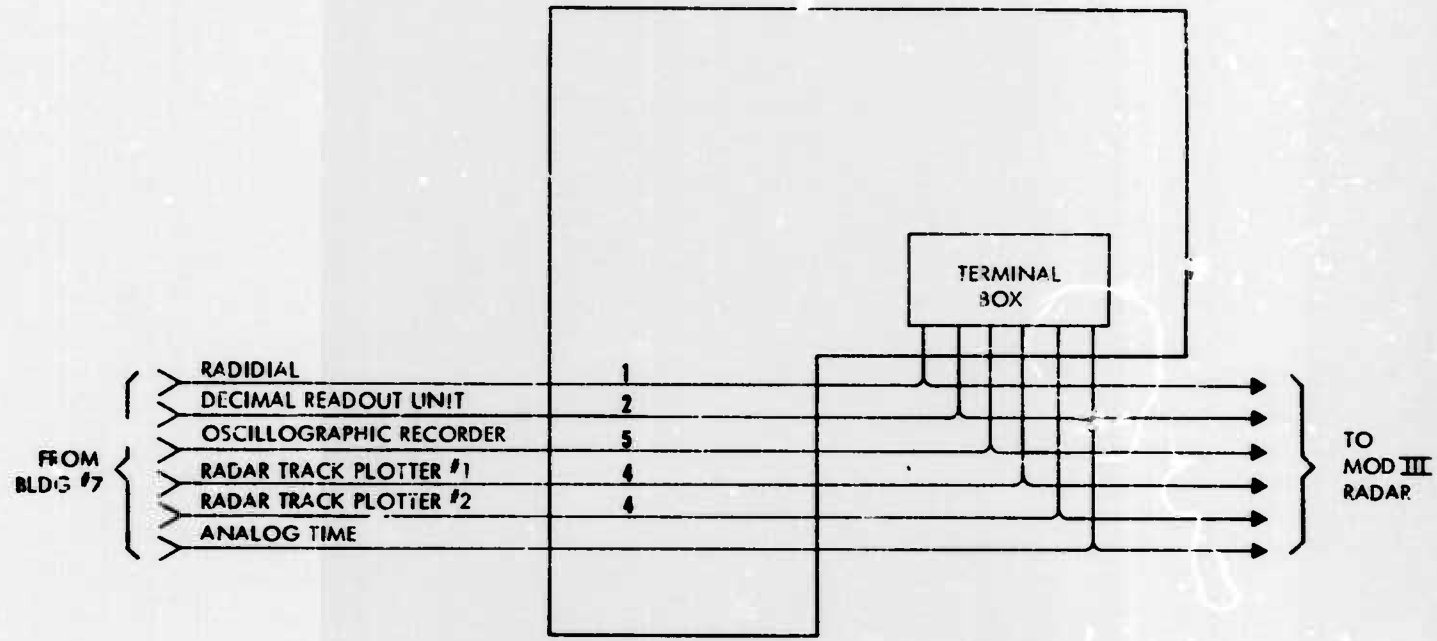


KEY:

1. RADIDIAL | DECIMAL TIME
2. DECIMAL READOUT UNIT | DECIMAL RANGE AND AZIMUTH
3. AMDPS | PARALLEL BCD TIME
4. RADAR TRACK PLOTTER | SERIAL TIME MARKS
5. OSCILLOGRAPHIC RECORDER | SERIAL BCD TIME

#25777

Figure 61. Nike Radar Van



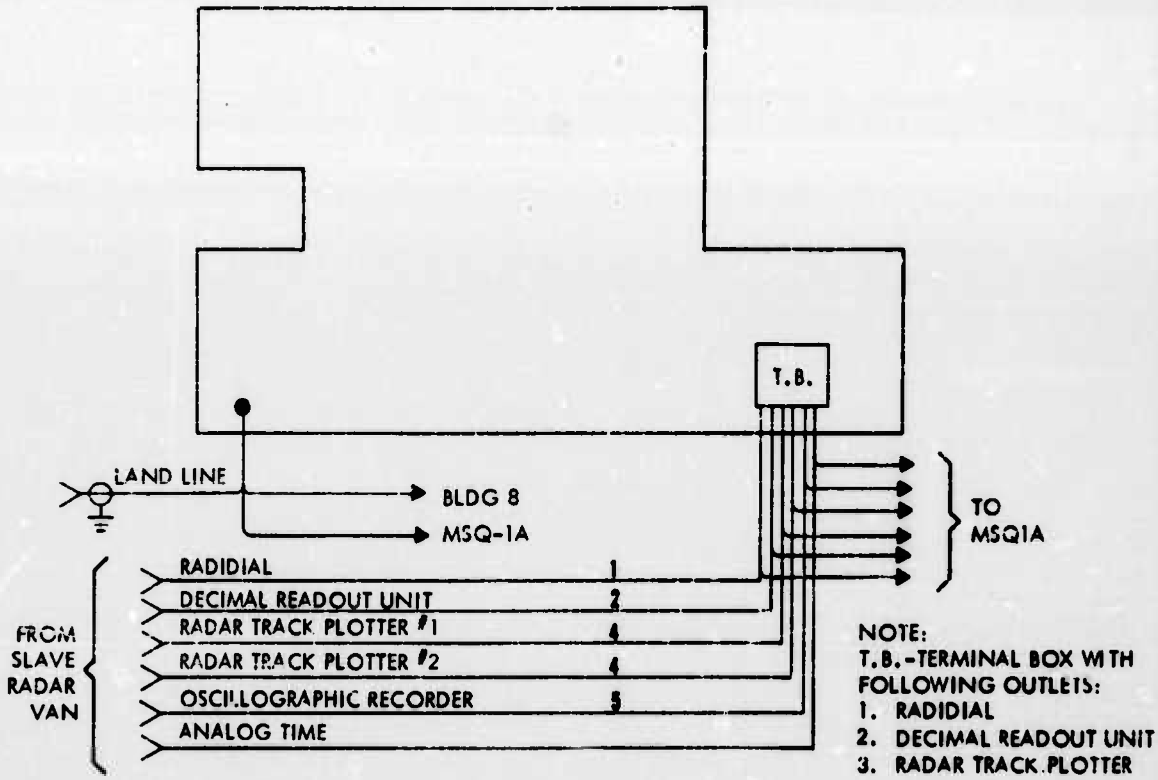
NOTE: T.B. – TERMINAL BOX WITH THE FOLLOWING OUTLETS
1. RADIDIAL
2. DECIMAL READOUT UNIT
3. OSCILLOGRAPHIC RECORDER

KEY:
1. RADIDIAL
2. DECIMAL READOUT UNIT
3. AMDPS
4. RADAR TRACK PLOTTER
5. OSCILLOGRAPHIC RECORDER

DECIMAL TIME
DECIMAL RANGE AND AZIMUTH
PARALLEL BCD TIME
SERIAL TIME MARKS
SERIAL BCD TIME

#25779

Figure 62. Slave Radar Van

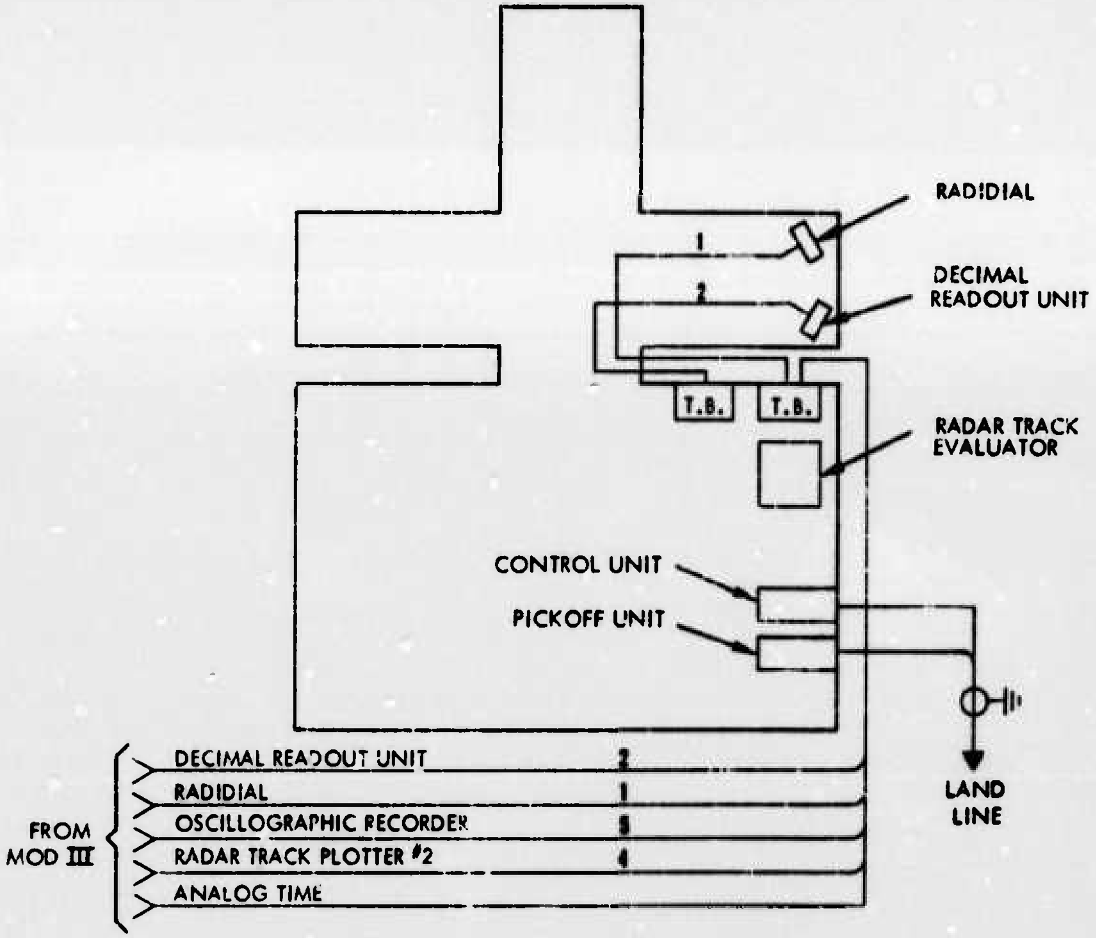


KEY:

1.	RADIDIAL	DECIMAL TIME
2.	DECIMAL READOUT UNIT	DECIMAL RANGE AND AZIMUTH
3.	AMDPS	PARALLEL BCD TIME
4.	RADAR TRACK PLOTTER	SERIAL TIME MARKS
5.	OSCILLOGRAPHIC RECORDER	SERIAL BCD TIME

#25780

Figure 6_. Mod III Radar Van



NOTE:

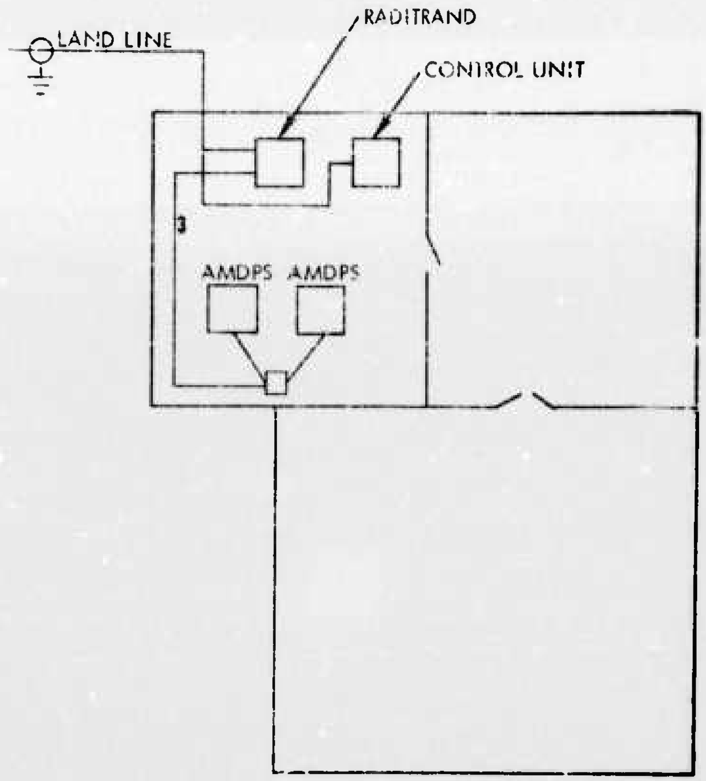
T.B.- TERMINAL BOX WITH THE FOLLOWING OUTLETS
1. RADIDIAL
2. DECIMAL READOUT UNIT

KEY:

1. RADIDIAL	DECIMAL TIME
2. DECIMAL READOUT UNIT	DECIMAL RANGE AND AZIMUTH
3. AMDPS	PARALLEL BCD TIME
4. RADAR TRACK PLOTTER	SERIAL TIME MARKS
5. OSCILLOGRAPHIC RECORDER	SERIAL BCD TIME

#25773

Figure 64. MSQ-1A Radar Van



KEY:

1. RADIDIAL	DECIMAL TIME
2. DECIMAL READOUT UNIT	DECIMAL RANGE AND AZIMUTH
3. AMDPS	PARALLEL BCD TIME
4. RADAR TRACK PLOTTER	SERIAL TIME MARKS
5. OSCILLOGRAPHIC RECORDER	SERIAL BCD TIME

#25774

Figure 65. Building #8

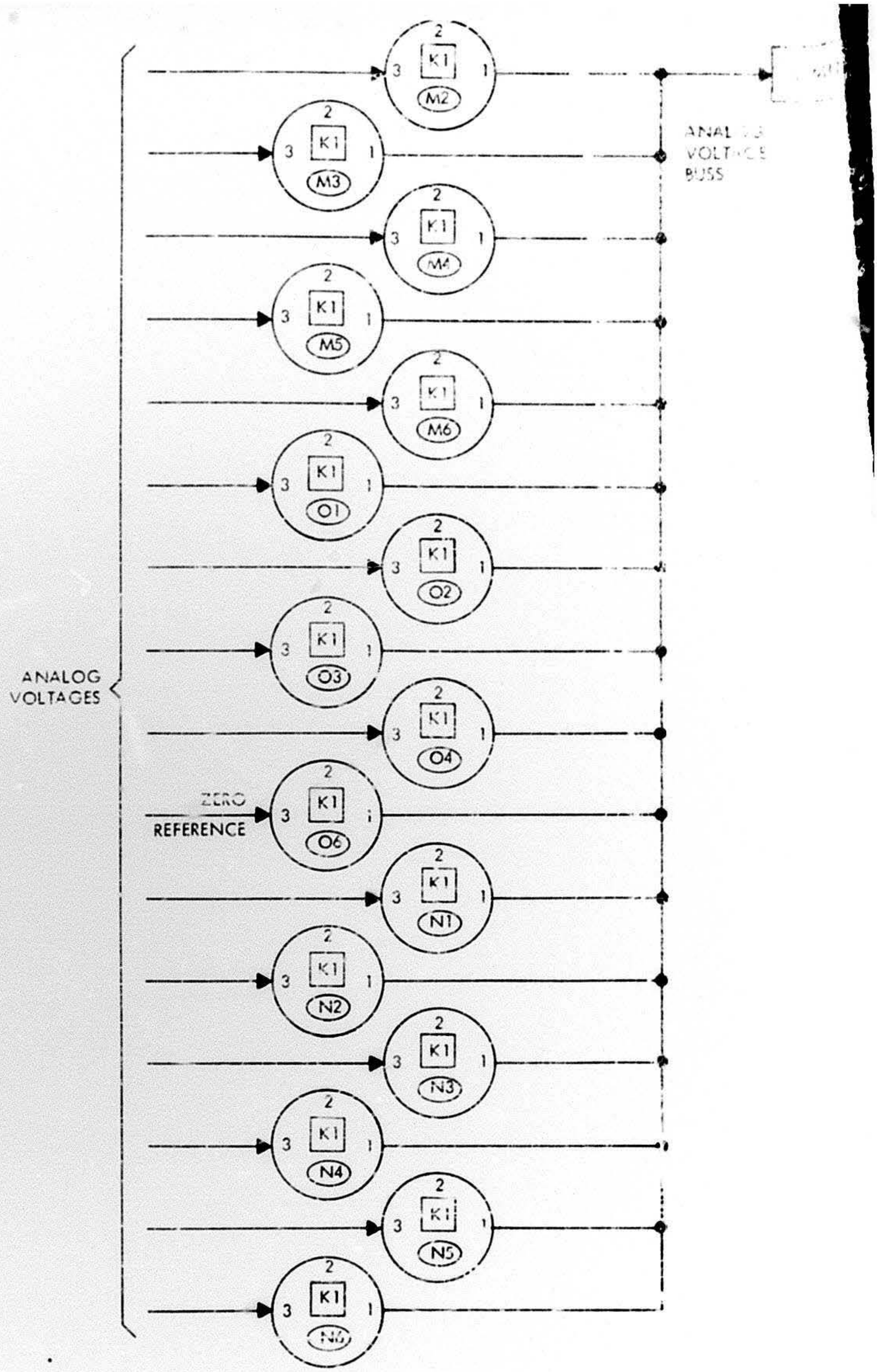


Figure 66. Recommended Analog Readin – AMDPS (MOD)